ANGELES PUBLIC LIBRARY
SEP 1 - 1959

JOURNAL of the AIR POLLUTION CONTROL ASSOCIATION

STACKS

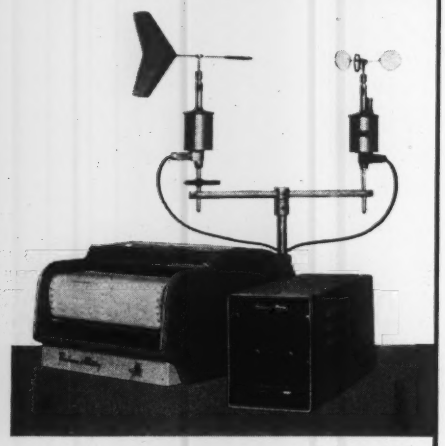
Founded 1907

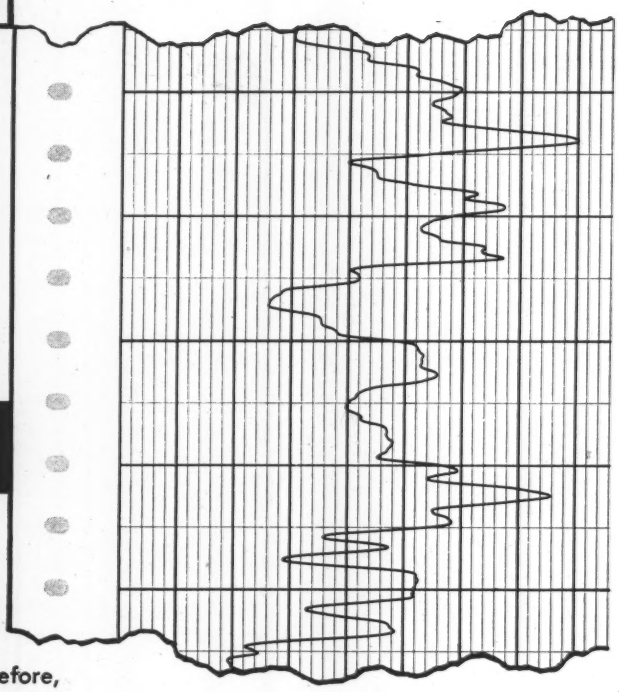
SCIENCE & TECHNOLOGY

Award Winners

(See Page 75)

WRITTEN BY THE WIND





high resolution recording system

Sliced up thinner than ever before, the wind can record itself with a new maximum of resolution in the Beckman & Whitley Type F System. This not only permits a more intimate documentation of the features of the winds, but, even where detailed records are not required, offers many advantages for fixed-station and system-telemetering uses.

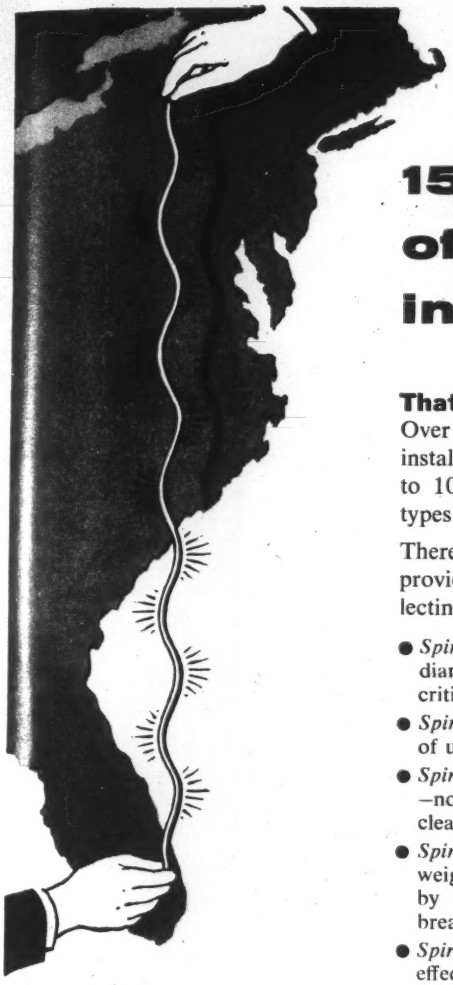
Operating from standard 115-volt 60-cps supply, the Type F can be used in portable applications where the increased resolution is needed, by the addition of an accessory battery-operated power supply.

Sample chart illustrated, produced by typical recorder shown, reveals fine, smooth detail recorded where maximum chart width is six miles per hour at a chart speed of 6-in. per min. Translator unit, designed for either bench-top or rack mounting, permits instantaneous switching between the four scales calibrated to maxima of 6, 12, 30, and 60 miles per hour.

For further information write:

Beckman & Whitley INC.

SAN CARLOS 4 CALIFORNIA

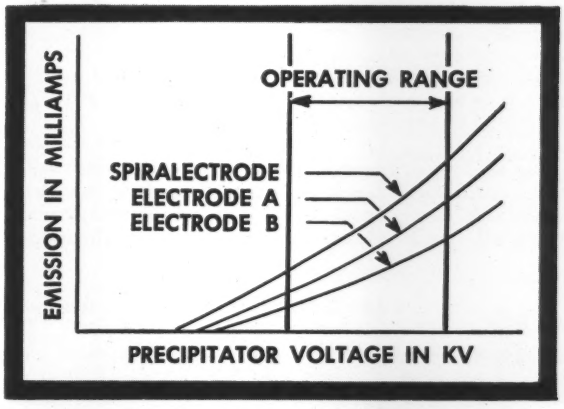


1500 miles of Spiralectrodes in Precipitator Service!

That's real proof of superior performance. Over 1500 miles of these emitting electrodes have been installed in 'SF' electric precipitators . . . delivering 50 to 100% more electron emission than conventional types of electrodes.

There are sound reasons why Buell *Spiralectrodes* are providing superior emitting efficiency in actual dust collecting applications.

- *Spiralectrodes* are *"emission engineered"* – pitch and diameter are custom designed for each application . . . of critical importance with high resistivity dust.
- *Spiralectrodes are precision made from stainless steel*– of uniform quality, corrosion-resistant.
- *Spiralectrodes minimize efficiency-loss of dust build-up* –no horizontal surface to collect dust, positive rapping cleans electrodes.
- *Spiralectrodes maintain predetermined tension* – (no weights required) . . . dampen effect of vibration caused by electrical pulsation, thereby minimizing electrode breakage.
- *Spiralectrodes'* controlled area emission stops sparking effect of "point emission."



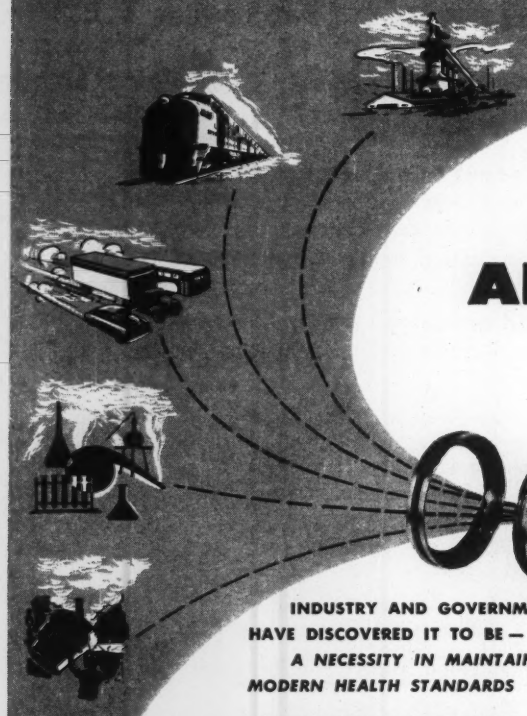
Above chart illustrates the superior emission of the Spiralectrode: its corona voltage is lower and its emission is higher than other types of emitting electrodes over the entire operating range of industrial precipitator voltage.

The superior operating characteristics of Spiralectrodes contribute to continued high efficiency of Buell 'SF' Precipitators. Detailed information of this and other exclusive features are described in a booklet, "Buell 'SF' Electric Precipitators." Send for your copy: write Dept. 51-H, Buell Engineering Company, Inc., 123 William Street, New York 38, New York.

buell®

Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**

TO COMBAT AIR POLLUTION . . .



Staplex
TRADE MARK

HI-VOLUME AIR SAMPLER

INDUSTRY AND GOVERNMENT HAVE DISCOVERED IT TO BE—
A NECESSITY IN MAINTAINING MODERN HEALTH STANDARDS

The STAPLEX HI-VOLUME AIR SAMPLER has proven to be a basic instrument in combating and controlling air pollution. Time-tested . . . excellent for both indoor and outdoor sampling . . . this sampler accomplishes in 10 minutes what previous units required 36 hours to do.

Accurately samples large volumes of air containing particulate matter as small as 1/100th of a micron in diameter through use of filter papers. Standard filter paper 4 inches in diameter. 6″ x 9″ and 8″ x 10″ adapters available. Other sizes to order.

Hundreds now in use by Industry and all types of government health agencies, Municipalities, Insurance Companies, etc. to accurately measure factory health hazards, atmospheric conditions, smoke abatement, smog, for mine inspections, and many other applications.

write for details

THE Staplex COMPANY
AIR SAMPLER DIVISION
777-D FIFTH AVE., BROOKLYN 32, N. Y.

NAME .....
COMPANY .....
ADDRESS .....

8-59

FOUNDED 1907

JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

Formerly "Air Repair"

A Quarterly Journal
Devoted To
Air Purification

Editor: Arnold Arch
Associate Editor: Pat Truschel
Assistant Editor: Norma Gorst

© Copyright, 1959
Air Pollution Control Association
Printed in the United States

AIR POLLUTION CONTROL ASSOCIATION
4400 Fifth Avenue
Pittsburgh 13, Pa.

Publications Committee 1958–59

B. E. Sawyer, Chairman
Henry E. Aldrich, Joseph McCabe,
D. H. Hutchison, E. Q. Camp,
W. A. Carter, Robert L. Chass

Editorial Review Committee 1958–59

W. C. L. Hemeon, Chairman
C. A. Bishop, M. D. Thomas,
G. P. Larson

The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

THE JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION is published February, May, August, November, with editorial and executive offices at 4400 Fifth Avenue, Pittsburgh 13, Pa.

Second class mail postage paid at Pittsburgh and at additional mailing office.

Subscription Price $10.00 per year.

CONTENTS

AUGUST 1959 **VOL. 9, NO. 2**

Long Range Cloud Diffusion in the Lower Atmosphere
B. P. Leonard, Jr. **77**

Stainless Steel Anti-smog Mufflers—Cut Air Pollution
Industrial Publicity Department, Communications Counselors, Inc. **83**

Performance of a Flue-Fed Incinerator
E. R. Kaiser, J. Halitsky, M. B. Jacobs, and L. C. McCabe **85**

Abstracts of Recent Legal Decisions Relating to Air Pollution
Legal Committee **92**

Engineering and Maintaining In-Plant Air Pollution Control
O. C. Thompson **94**

Filters and Filter Media for the Cement Industry
Richard F. O'Mara and Carl R. Flodin **96**

Investigating Inhalation Hazard Using Synthetic Radioactive Fallout
William B. Lane **102**

Plants Pollute Air
Cdr. Sidney Goren **105**

Continuous Determination of Carbon Monoxide and Hydrocarbons in Air by a Modified Infrared Analyzer
Morris B. Jacobs, M. M. Braverman, and Seymour Hochheiser **110**

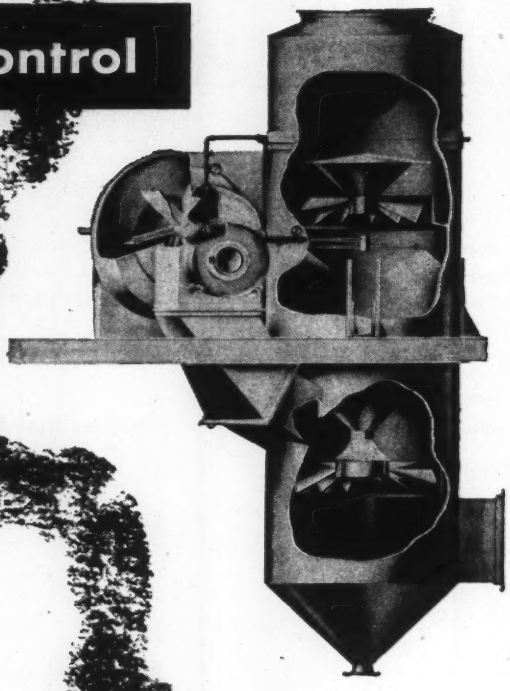
Air Pollution Control Is Good Business
William R. Bradley **115**

Classified **119**

Index to Advertisers **122**

Award Winners — Milton Reizenstein (*second from left*), past president of APCA, presents the Frank A. Chambers Award to Dr. Robert Eckles Swain (*third from left*), Professor Emeritus of Chemistry at Stanford University while Charles N. Howison (*left*), honorary membership recipient, and John F. Barkley, winner of the Richard B. Mellon Award, look on.

. . . in wet dust control



NEW DUCON DYNAMIC WASHERS

Patented

RECOVER DIFFICULT DUSTS EFFICIENTLY AND ECONOMICALLY

Ducon UW-4 Dynamic Wet Dust Collectors have added a new dimension in dust recovery. They have replaced, with outstanding success, many more costly and less effective dust collectors in the recovery of "difficult" materials, such as fine and abrasive dusts in kilns, rotary driers and other applications.

The UW-4 Washers are also ideal for high loading conditions where maximum efficiency is desired.

Ducon UW-4 washers offer other unique advantages, including constant air capacity, low water consumption and rugged construction. They are self-cleaning and fire and explosion proof.

For complete information write for Bulletin W-7456.

DUST CONTROL SYSTEMS AND EQUIPMENT — DUCON

the name in DUst CONtrol

THE Ducon COMPANY INC.

147 EAST SECOND STREET • MINEOLA, L. I., NEW YORK

Canadian Branch:
THE DUCON COMPANY of CANADA, Ltd.,
1131 Pettit St., BURLINGTON, ONTARIO

CYCLONES • CENTRIFUGAL WASH COLLECTORS • TUBULAR CLOTH FILTERS • DUST VALVES

Long Range CLOUD DIFFUSION *in the* LOWER ATMOSPHERE

B. P. LEONARD, JR., Convair, A Division of General Dynamics Corp., Fort Worth, Texas

Introduction

O. G. Sutton developed a diffusion model in 1932[1] which has proved successful in predicting cloud diffusion at short distances from the release point. This success at short distances has led to the wide-spread application of Sutton's equation for long range diffusion predictions, a practice which has been seriously questioned due to lack of theoretical or experimental justification. Indeed, experimental evidence has indicated that the parameters in Sutton's equation, assumed constant, are actually functions of the diffusion time. Recent long range cloud diffusion experiments demonstrate that the concern as to the applicability of Sutton's equation has been well founded. It appears that a modified diffusion equation is required to adequately represent cloud diffusion at long distances from the release point. To understand this, we must first consider some of the basic ideas used by Sutton in developing his diffusion equation.

G. I. Taylor,[2] using a statistical approach to the atmospheric diffusion problem, developed the following equation:

$$\overline{Y^2} = 2\overline{v^2}\int_0^t \int_0^{t_1} R(T)dTdt_1 \qquad (1)$$

where:

$\overline{Y^2}$ = mean square distance from an axis traveled by particles released at different (random) times and allowed to diffuse for a time t

$\overline{v^2}$ = mean square of the instantaneous velocities in the turbulent field (in the y direction)

$R(T)$ = Lagrangian Auto Correlation function which may be expressed in terms of the wind power spectrum:

$$R(T) = \int_0^\infty F(n)\cos(nt)dn \qquad (2)$$

where

n = frequency of turbulence

$F(n)$ = fraction of the turbulent energy lying between n and $n + d_n$ (the wind power spectrum normalized to an area of one)

Taylor further deduced that for small diffusion times:

$$R(T) \approx 1; \quad \overline{Y^2} \approx \overline{v^2}t^2 \qquad (3)$$

and for long diffusion times

$$\overline{Y^2} \rightarrow Kt \qquad (4)$$

Unfortunately, Taylor's equation cannot be used directly to predict cloud diffusion since (*1*) it describes the statistical motion of the individual particles with respect to a fixed axis on the ground and (*2*) very little is known about the behavior of $R(T)$.

The usual approach to development of a model for cloud diffusion is to first assume that matter will be distributed normally in the cloud. This assumption appears justified in view of the statistical nature of the phenomenon and because experimental evidence tends to verify it. The assumption of normal distribution leads directly to an expression for concentrations in a cloud puff:

$$N(x_1,y_1,z_1) = Q\exp\left[-(x_1^2/2\sigma_{x_1}^2) - \frac{(y_1^2/2\sigma_{y_1}^2) - (z_1^2/2\sigma_{z_1}^2)}{(2\pi)^{3/2}\sigma_{x_1}\sigma_{y_1}\sigma_{z_1}}\right] \qquad (5)$$

Where Q is the total matter in the cloud and the variance, σ_{y2}, is a function of the diffusion time.

To obtain a working model for predicting cloud concentrations, the functional relationship between the variance and diffusion time must be established. Basic diffusion theories provide only qualitative information on this relationship. Sutton, relying on the limiting values described by Taylor (equations 3 and 4), assumed:*

$$2\sigma_{x_1}^2 = C_{x_1}^2(\bar{U}T)^{(2-n)} = C_{x_1}^2(x)^{(2-n)} \qquad (6)$$

$$2\sigma_{y_1}^2 = C_{y_1}^2(\bar{U}T)^{(2-n)} = C_{y_1}^2(x)^{(2-n)} \qquad (7)$$

$$2\sigma_{z_1}^2 = C_{z_1}^2(\bar{U}T)^{(2-n)} = C_{z_1}^2(x)^{(2-n)} \qquad (8)$$

Where $\bar{U}$, T, and x are the mean wind speed, diffusion time and distance downwind from the release point. This set of assumptions should not be expected to be wholly satisfactory since Taylor's theory implies a transition period in which the values of the parameters "C" and "n" will change with diffusion time. The length of the transition period and the time at which it occurs could, therefore, have an important bearing upon the validity of the assumptions (equations 6, 7, and 8). It is informative to examine this problem in the light of wind power spectra data.

Wind Power Spectra

The key to cloud diffusion lies in the amount and frequency distribution of the turbulent energy in the atmosphere. Unfortunately, the precise spectrum (the Lagrangian spectrum) that is required is not readily measurable; however, a great deal of data has been obtained on the Eulerian* spectrum, and the two are certainly very similar. Theory and some limited data indicate that they may differ only by a phase shift. Therefore, a study of the Eulerian spectrum will certainly yield qualitative information on the Lagrangian spectrum.

Panofsky and Van der Hoven have made exhaustive studies of the Eulerian Wind Power Spectra near the ground.[3, 4] A brief summary of the most important features of the spectra is given here.

Effect of Presence of the Ground

One of the most striking features of wind power spectra is the difference between the vertical and horizontal spectra. Fig. 1 shows a comparison (the curves are plotted such that the area of a vertical strip represents the turbulent energy in that frequency range). The ground suppresses essentially all of the large scale turbulence in the vertical spectrum. The horizontal spectrum, on the other hand, contains the complete range of frequencies up to extremely large scales (periods) of turbulence.

Effect of Atmospheric Stability

In general, the effect of reduced solar

* The Lagrangian spectrum is measured in a parcel of air moving downwind. The Eulerian is the spectrum measured at a point fixed on the ground.

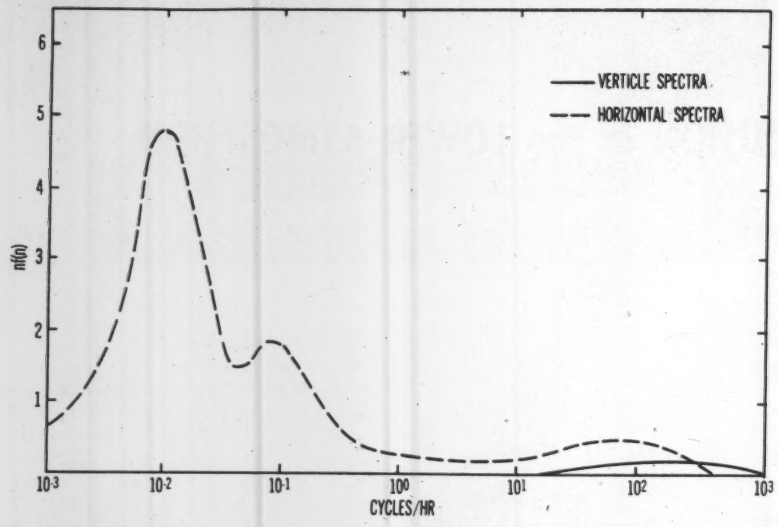


Fig. 1. Turbulent wind spectra for low radiation conditions (horizontal and vertical components).

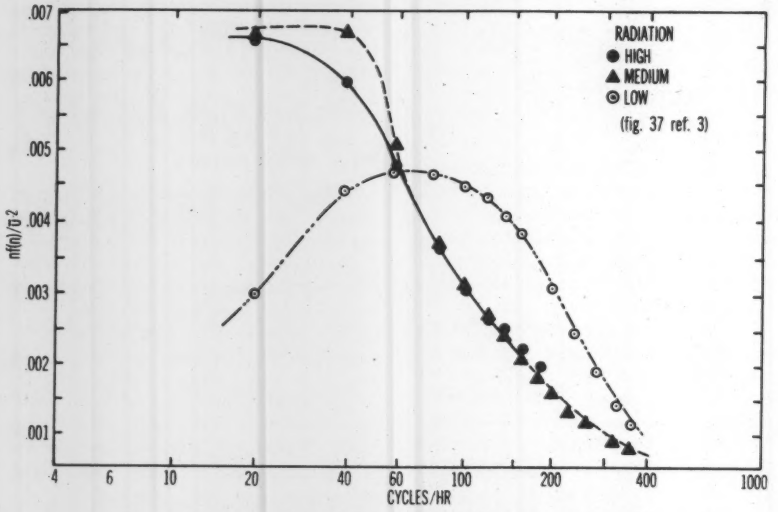


Fig. 2. Composite horizontal spectra (effect of atmospheric stability).

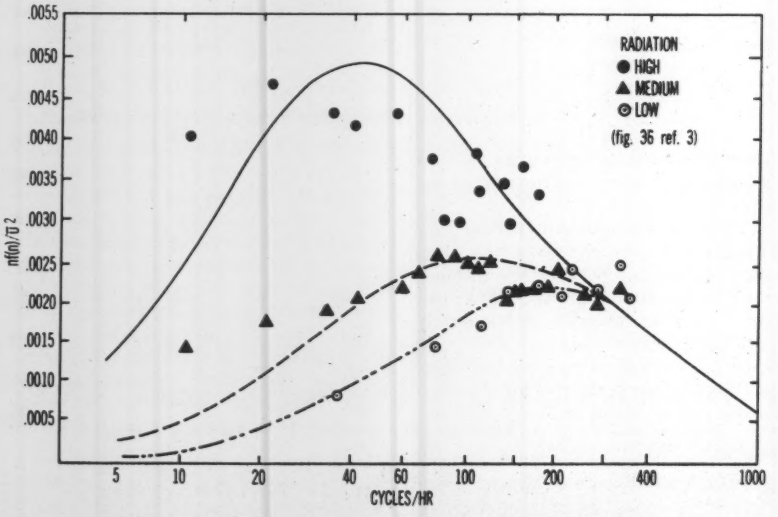


Fig. 3. Composite vertical spectra (effect of atmospheric stability).

radiation (increased stability) is to reduce the large scales of turbulence both in the horizontal and vertical spectra (Figs. 2 and 3). The authors presented the data normalized to the mean wind speed squared ($\overline{U^2}$) since they found evidence that the turbulent energy was proportional to that quantity. Van der Hoven, in a subsequent investigation,[4] found the larger scale turbulence (less than 10 cph) in the horizontal spectrum to be relatively insensitive to weather conditions.

Effect of Height Above the Ground

The effect of height above the ground is somewhat similar to that of solar radiation. The lower the height, the greater the suppression of large scale turbulence particularly for the vertical spectrum (Fig. 4).

Diffusion Model

Let us consider a cloud diffusing initially from a point source. We will retain the assumption of normal distribution of matter which yields equation (5) but reconsider the assumption for the functional form of the variance.

Taylor's limiting cases restated are:

For $\overline{Y^2}$ small compared to the scales of turbulence (diffusion time small):

$$\overline{Y^2} \approx 2\overline{v^2}t^2 \qquad (9)$$

For $\overline{Y^2}$ large compared to the scales of turbulence (diffusion time large)

$$\overline{Y^2} \approx Kt \qquad (10)$$

Considering the spectral data presented in the previous section it appears that:

1. Due to the radical difference in the vertical and horizontal spectra (Fig. 1), the limiting cases (9 and 10) should not occur at the same time in the horizontal and vertical planes.*
2. A condition near the limiting case described in equation (9) might be expected to exist in the horizontal for hours due to the presence of large scale turbulence.
3. The suppression of large scale turbulence in the vertical plane should lead to the limiting case of equation (10) in a time of the order of minutes.
4. The time at which the transition occurs in the vertical plane should decrease with increasing atmospheric stability and decreasing height due to greater suppression of large scale turbulence.
5. Diffusion in the horizontal plane should be larger than in the vertical plane and should be less sensitive to weather conditions due to the large scale horizontal turbulence and its relative constancy with varying weather conditions.[4]

On the basis of these conclusions, it

* This possibility has been suggested by J. Z. Holland.[5]

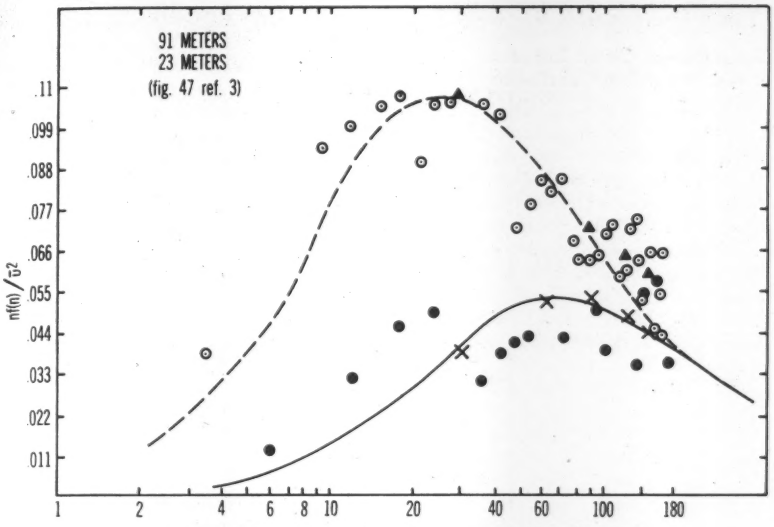


Fig. 4. Composite vertical spectra (effect of height above ground).

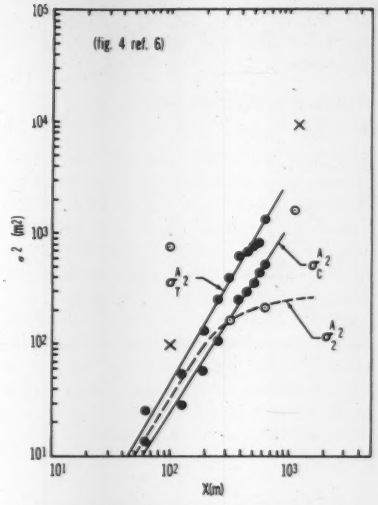


Fig. 5. Horizontal and vertical variancies (inversion conditions).

appears that Sutton's assumption on the functional form of the variances (equations 6, 7, and 8) requires modification. The most important factor is that diffusion in the horizontal and vertical planes is expected to be typical of the two extremes suggested by Taylor (equations 9 and 10). This implies that a better assumption for the functional form of the variances is:

$$2\sigma_{x_1}^2 = C_{x_1}^2(\bar{U}T)^{m_{x1}} = C_{x_1}^2 x^{m_{x1}} \quad (11)$$

$$2\sigma_{y_1} = C_{y_1}^2(\bar{U}T)^{m_{y1}} = C_{y_1}^2 x^{m_{y1}} \quad (12)$$

$$2\sigma_{z_1} = C_{z_1}^2(\bar{U}T)^{m_{z1}} = C_{z_1}^2 x^{m_{z1}} \quad (13)$$

These functional forms might be expected to hold in regions other than those where the transition to the limiting case (equation 10) is occurring. Since the spectral data indicate this should occur in the order of minutes for the vertical and not for hours in the horizontal, the assumed form for the variance might be expected to be valid for large regions of diffusion time.

Using the above assumption and equation (5), the equation for concentrations in a cloud plume is found to be:

$$X(x, y, z) = \frac{Q_0[-(y^2/C_y^2 x^{2m_y}) - (z^2/C_z^2 x^{2m_z}]}{\pi \bar{U} C_y C_z x^{m_y + m_z}} \quad (14)$$

This equation differs from Sutton's only in that the exponents of x is well as the coefficients have different values in the different planes. However, this modification forces abandonment of the physical interpretation of the parameters given by Sutton.

Cloud dimensions from equation (14) are:

$$2y = 2\left[\ln \frac{1}{P}\right]^{1/2} C_y x^{m_y} \quad (15)$$

$$2z = 2\left[\ln \frac{1}{P}\right]^{1/2} C_z x^{m_z} \quad (16)$$

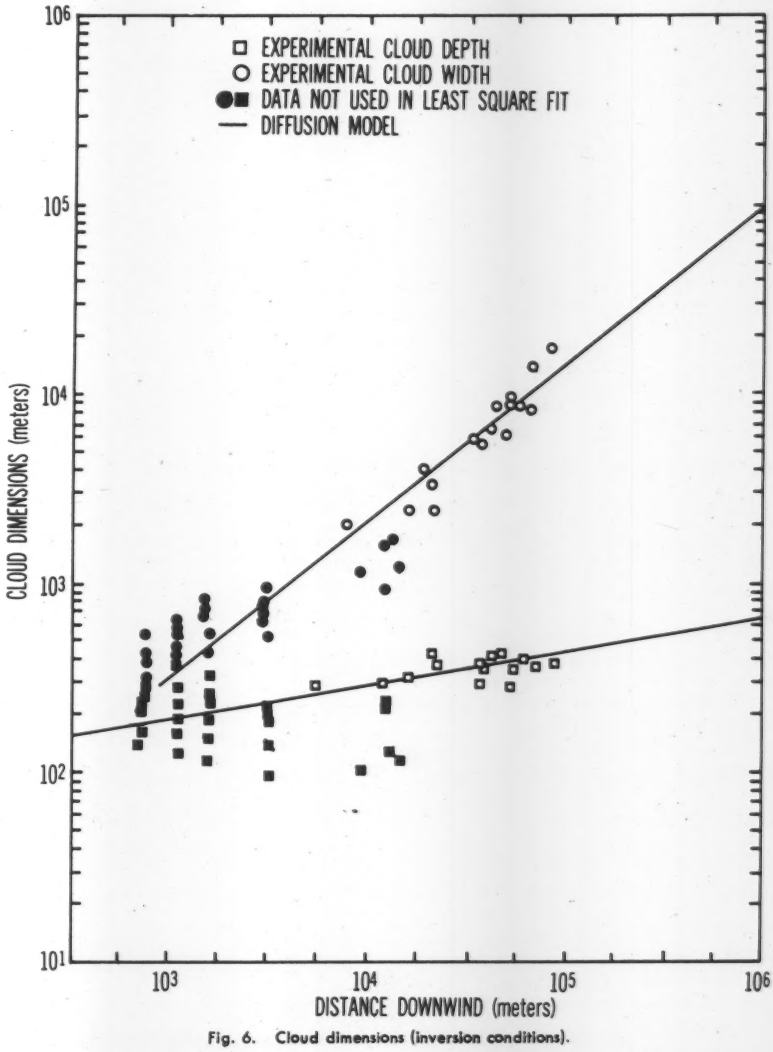


Fig. 6. Cloud dimensions (inversion conditions).

where P is the ratio of the concentration at the edge of the cloud to that on the centerline.

Transition Region of the Variance

Hilst[6, 7] and his co-workers have made an extensive study of the behavior of the variances in the first few minutes of diffusion of a cloud plume. Typical behavior of the vertical and horizontal variances under inversion conditions is demonstrated in Fig. 5. σ_z^2 is the vertical variance. σ_T^2 and σ_c^2 are the horizontal variances with and without the effect of cloud meandering. It can be seen that the transition implied by the vertical power spectrum is present in the first few hundred meters of travel downwind. Data taken under different degrees of stability all evidence the same behavior with the transition region occurring at shorter times for the cases of increased stability.[7] As implied by the horizontal spectrum, the horizontal variances show no evidence of such a transition in this region.

Long Range Cloud Diffusion Under Inversion Conditions

Thomas and Carpenter[8] have made long range measurements in cloud plumes from large stationary power plants. The data include both cloud sampling (concentrations) and visual observations of the cloud dimensions. The centerline of the plumes occurred in the region of 300 to 400 m above the ground. The data, taken on different days and in some cases at different plants, demonstrate remarkably similar diffusion rates.

As stated previously, diffusion theories are not yet adequate for predicting the values of the parameters in equations 11, 12, and 13. It appears, therefor, that a fit of the experimental data is the next best approach. Fig. 6 shows a least square fit of the experimental data for cloud dimensions using equations 15 and 16 with $P = 0.1$. Only the open symbols were used in the analysis (the other data were obtained at a later date). Values obtained for the parameters are given in Table I. Fig. 7 shows the experimental centerline concentrations and predictions using the parameter values given in Table I with a mean wind speed of 3 m/sec. Values of the predicted cloud concentrations (equation 14) have been multiplied by a factor of two to account for reflection from the ground and, in some cases, from an inversion layer at the top of the cloud. Deviations in the region of 10^3 m are apparently due to the fact that the cloud had an appreciable width at the point of release. It is interesting to note that the centerline predictions shown here also compare favorably with oil fog concentration data obtained at Brookhaven.[9]

Table I—Diffusion Parameter Values (Long Range—Inversion Conditions)

m_y	0.84
C_y	0.3
m_z	0.18
C_z	18.00

The behavior of the variances implied by these data is quite consistent with the short range data discussed in the previous section with the exception that the absolute values are somewhat larger. This may be due to the greater height of the cloud as well as to differences in the degree of stability.

Long Range Diffusion Under Lapse Conditions

Braham, Seely, and Crozier made concentration measurements of a fluorescent pigment at large distances from the release point.[10, 11] The data, taken under lapse conditions, were obtained on different days and do not contain sufficient detail for an analysis like that presented in the previous section. However, certain general conclusions can be drawn.

Concentration maps of the cloud plumes demonstrate that the diffusion becomes anisotropic at large distances even under lapse conditions. It appears that the cloud depths did not exceed about 1500 m while the width of the clouds ranged from about 6000 to 24,000 m at diffusion distances of about 8000 to 50,000 m respectively.

Sufficient data were obtained[10] to estimate values of the parameters in the horizontal plane (equation 12). Fig. 8 shows a fit of the diffusion model to the data with $m_y = 0.84$ and $C_y = 0.93$.

Peak cloud concentrations are shown in Fig. 9. The data, taken on different days, have been corrected to a mean wind speed of 11.2 m/sec assuming concentrations to be inversely proportional to the mean wind speed. The concentrations shown for the diffusion model were obtained by using the parameter values shown in Table II.

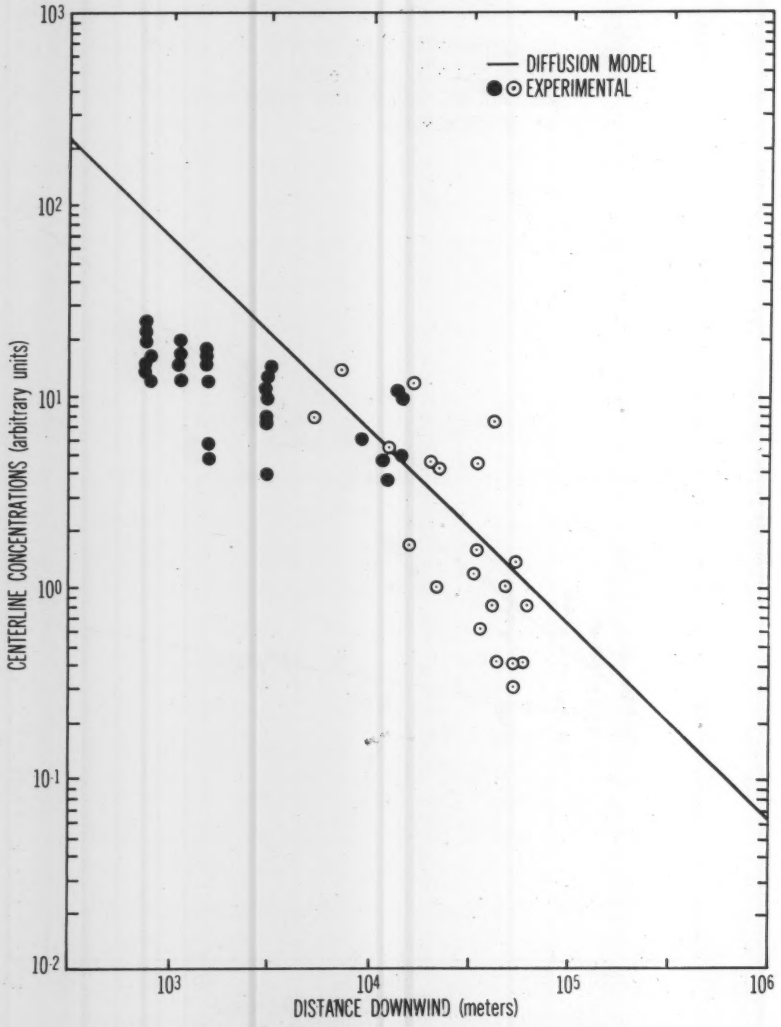


Fig. 7. Cloud centerline concentrations (inversion conditions).

Table II—Diffusion Parameter Values (Long Range—Lapse Conditions)

m_y	0.84
C_y	0.93
m_z	0.18
C_z	100.00

The value of m_z was chosen somewhat arbitrarily to coincide with the value obtained for inversion conditions. The associated value of $C_z = 100$ yields reasonably good comparison with experimental data in the region of 3000 to 30,000 m. The values of the parameters are at least qualitatively consistent with the limiting cases of Taylor and the experimental power spectra. Beyond 30,000 m, the data imply a further reduction in a diffusion rate. There is some indication that this is due to a reduction in diffusion rates both in the vertical and the horizontal.

Implications to Reactor Hazard Predictions

Clearly there is no single set of diffusion parameters which will represent diffusion under the broad categories of lapse or inversion conditions. In spite of this fact, it is common practice to attempt to do so in the interest of simplifying the difficult problem of predicting reactor hazards. It is interesting to compare the parameter values generally in use with those obtained in this analysis.

Table III shows presently accepted parameter values used with Sutton's equation for inversion conditions. The more recent Brookhaven values[11] reflect the greater horizontal spread of the cloud. Comparisons of predicted centerline concentrations are shown in Fig. 10. The modified equation implies substantially lower concentrations than previously predicted. This is particularly true for short diffusion distances.

Table III—Accepted Parameter Values (Inversion Conditions)

Parameter	Previously Accepted Values	Brookhaven Values
n	0.55	0.55
C_z	0.05	0.05
C_y	0.05	0.40
$\bar{U}$	3 m/sec	3 m/sec

Table IV presents parameter values currently in use for lapse conditions.

Table IV—Accepted Parameter Values (Lapse Conditions)

n	0.25
C	0.4
$\bar{U}$	5 m/sec

Comparisons of centerline concentrations are shown in Fig. 11. The discrepancy of an order of magnitude at 10^5 m is due almost entirely to the difference in the predictions for vertical diffusion.

It must be emphasized that parameter values presented here are for long range diffusion (past the transition region of the vertical variance). They are not applicable in the first 1000 to 2000m downwind under inversion conditions. Under lapse conditions, the distance is not as well defined but probably extends as far as 5000 to 8000 m.

It appears that cloud concentrations at long distances have been overestimated for inversion conditions and underestimated for lapse conditions. The net effect of these predictions is to reduce markedly the differences in predicted long range hazards for different weather conditions.

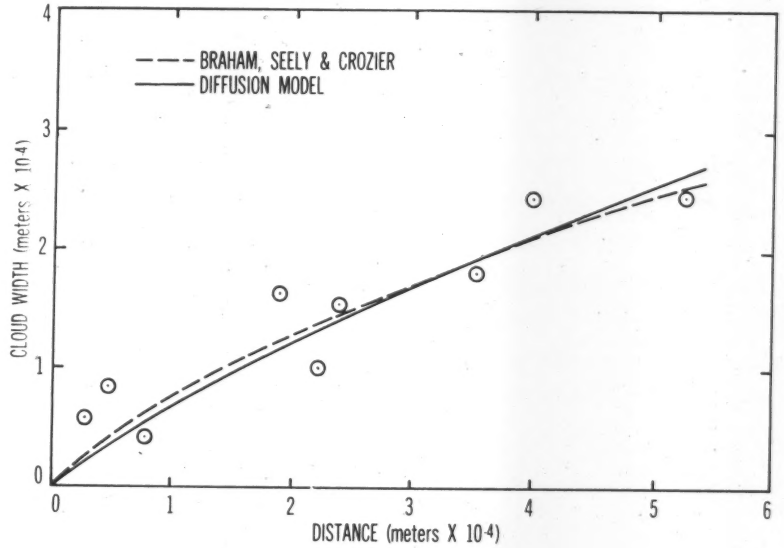


Fig. 8. Cloud width (lapse conditions).

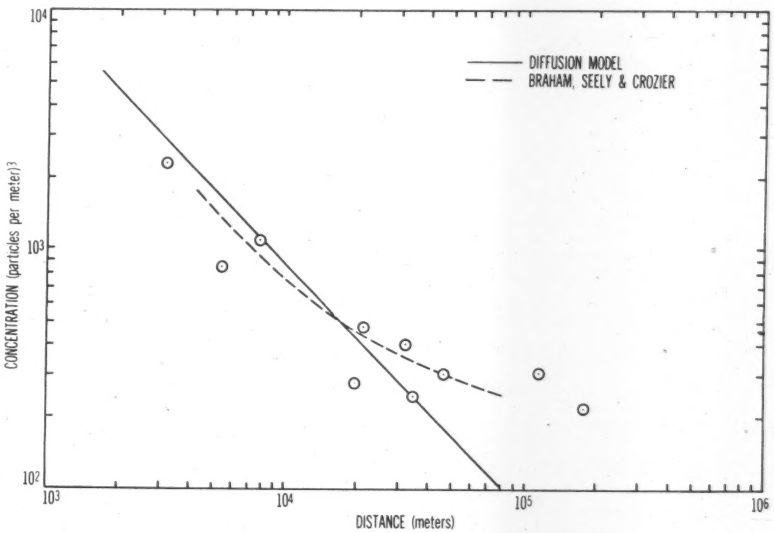


Fig. 9. Cloud centerline concentrations (lapse conditions).

Conclusions

On the basis of the data presented here the following conclusions may be drawn:

1. Long range cloud diffusion is anisotropic, regardless of weather conditions, due to suppression of large scale turbulence by the ground.
2. Anisotropic diffusion is greatly magnified under stable atmospheric conditions due to increased suppression of large scale turbulence.
3. Cloud concentrations at large distances are roughly inversely proportional to the diffusion distance with a major portion of the diffusion occurring in the horizontal plane. This effect is relatively insensitive to weather conditions.
4. Cloud dimensions and, therefore, concentrations differ significantly with weather conditions. This is due almost

entirely to differences in diffusion rates in the first one to three miles of diffusion distance.

The results and conclusions presented here are based on very limited data. They should, therefore, be considered tentative until more data and analyses are available. In particular, values of the diffusion parameters should be used with caution because of their dependence upon weather conditions and source height. However, in spite of these limitations, it appears that the diffusion model and associated parameter values presented here will permit more realistic predictions of long range reactor hazards.

REFERENCES

1. G. I. Taylor, "Diffusion by Continuous Movements," *Proc. Lond. Math. Soc.*, **20**, 196–212 (1921).
2. O. G. Sutton, "A Theory of Eddy Diffusion in the Atmosphere," *Proc. Roy. Soc. Lond.* **A135**, 143–165 (1932).
3. I. Van der Hoven and H. A. Panofsky, *Final Report on Statistical Properties of the Vertical Flux and Kinetic Energy at 100 Meters*, Air Force Cambridge Research Center (June 30, 1954).
4. I. Van der Hoven, "Power Spectrum of Horizontal Wind Speed in the Frequency Range from 0.0007 to 900 Cycles per Hour," *Journal of Meteorology*, **13**:4 (August, 1956).
5. J. Z. Holland, *Progress in Applications of Meteorology to Peaceful Uses of Atomic Energy*, U. S. Atomic Energy Commission, Wash., D. C. (July 2, 1958).
6. G. R. Hilst, "The Dispersion of Stack Gases in Stable Atmospheres," J. AIR POLLUTION CONTROL ASSN., **7**, 3 (November, 1957).
7. G. R. Hilst and C. L. Simpson, "Observations of Vertical Diffusion Rates in Stable Atmospheres," *J. Meteorology* (February, 1958).
8. F. W. Thomas and S. B. Carpenter, Wilson Dam, Ala., Private communication.
9. M. E. Smith, et al., *The Variation of Effluent Concentrations During Temperature Inversions*, BNL 3237.
10. R. R. Braham, et al., "A Technique for Tagging and Tracing Air Parcels," *Trans.*, **33**, 6, Am. Geophysical Union (December, 1952).
11. W. D. Crozier and B. K. Seely, "Concentration Distributions in Aerosol Plumes Three to Twenty-Two Miles from a Point Source," *Trans.*, American Geophysical Union (February, 1955).

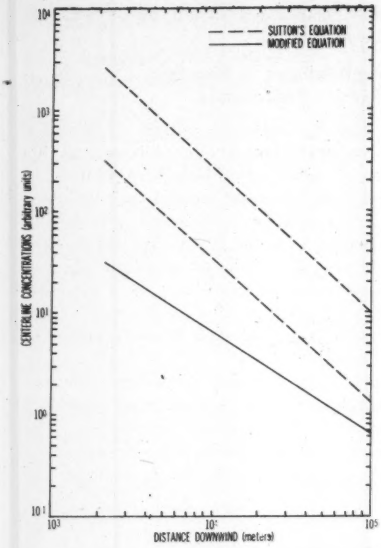


Fig. 10. Cloud centerline concentrations (inversion conditions).

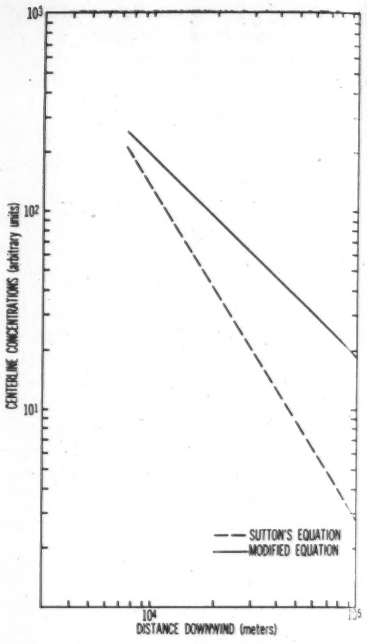


Fig. 11. Cloud centerline concentrations (lapse conditions).

Stainless Steel ANTI-SMOG MUFFLERS—CUT *Air* POLLUTION*

By **INDUSTRIAL PUBLICITY DEPARTMENT, COMMUNICATIONS COUNSELORS, INC.,** New York, N. Y.

Afterburner-type mufflers have proved to be 97 percent effective in eliminating smog-producing hydrocarbons from engine exhausts (one of the principal causes of air pollution) on Los Angeles City School and Transit System buses.

Users report less back pressure resulting in increased horsepower and gas mileage and improved engine performance. Some of the mufflers have successfully operated more than 100,000 miles without failure.

The muffler is almost entirely fabricated from chromium-nickel stainless steel, in order to resist oxidation and corrosion at the high operating temperatures.

There has been a long-felt need for suitable smog-smothering devices for the exhausts of trucks and buses in the Southern California area.

According to the Los Angeles Air Pollution Control District figures, at least half of the air pollutants contaminating the city's atmosphere are directly traceable to motor vehicle exhausts. Many hundred thousand gallons of hydrocarbons are released into the atmosphere daily by the near 3,000,000 vehicles operating in the area.

In August, 1956, installation of antismog mufflers was started on the Los Angeles City Schools' 81 big passenger buses. Twenty new school buses recently delivered arrived with these mufflers as original equipment. The outlying school districts are now beginning to install these mufflers on their buses. Alhambra, Calif., is particularly active in this respect.

When an antismog muffler is installed on one bus of a school fleet, it is usually not long before both drivers and the children are enthusiastically urging that these mufflers be installed on all the buses. As a result the local Los Angeles Transit System is continuing a program of installing these mufflers and is highly pleased with the results.

The muffler is an afterburner which, according to automotive laboratory reports, eliminates 97 percent of the hydrocarbons and 81 percent of the carbon monoxide from engine exhausts. Laboratory tests, made with a gasoline-powered bus produced a satisfactory over-all removal of the smog-forming hydrocarbons.

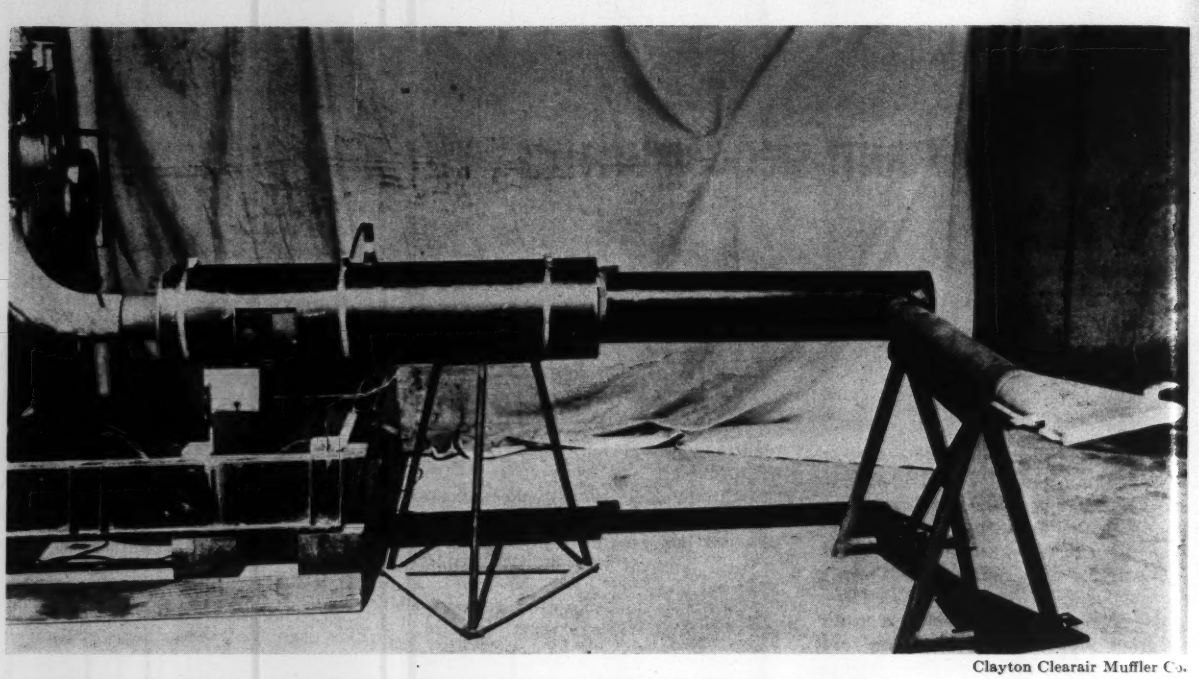
The muffler is designed to dispose of the unburned fuels present in the exhaust system of a gasoline engine. It consists of a primary burning tube (pilot tube) through which the bulk of the exhaust gases pass during operations of low exhaust volume. Air is introduced through an adjustable opening into this tube and the resulting mixture is ignited by a long-reach spark plug.

As the exhaust volume increases, the excess exhaust gases are carried through an area surrounding the pilot tube and receive air from an adjustable rectangular opening in the muffler shell. This portion of the exhaust mixture is burned in the same combustion area as that of the pilot tubes. The exit tube of the muffler is baffled to prevent the flame from protruding from the tail

Clayton Clearair Muffler Co.

Fig. 1. Anti-smog muffler being installed by mechanic on a Los Angeles School bus. George W. Talbott (at left), general manager of Clayton Clearair Muffler Company, Los Angeles, Cal., stands behind a cutaway model.

* Published in *Fleet Owner*, June, 1958.



Clayton Clearair Muffler Co.

Fig. 2. Test setup of anti-smog muffler in Automotive Combustion Laboratory of Air Pollution Control District for County of Los Angeles. Muffler was connected to newly overhauled Mack Thermadyne EN 672 bus engine. Results showed reduction of 97% hydrocarbons, 81% carbon monoxide, 69% acetylene, and 39% aldehydes.

pipe.

The spark plug is fired by a standard 6-v coil in series with a 6-v engine coil. The two coils produce the same relative resistance in the primary circuit as that on one 12-v coil. Thus a spark is induced in the afterburner spark plug every time the distributor points break. In order to prevent the afterburner plug firing during the initial starting period where excessive richness might cause a backfire, an oil pressure switch interrupts the circuit until normal oil pressure is produced. In this way, the muffler is completely safe and automatic.

A throttle delay, or dashpot, controls the closing of the carburetor butterfly valve during deceleration. By retarding throttle closing, it supplies air through the carburetor intake to burn residual fuels in the engine manifold and cylinder system more completely. This action also prevents high intake vacuum to reduce the surge of fuel into the exhaust system.

In order to withstand operating temperatures up to 1300°F, Type 321 stainless steel is used for the inner shell of the muffler and for all internal parts, including the pilot air blade, venturi system, tubes, and burner cones. Muffler components are largely sheet metal stampings or formed and welded subassemblies. Spot, seam, and heliarc welding play an important part in the fabrication.

The current model was designed for heavy-duty gasoline-powered trucks and buses with 550 to 750 cu in. piston displacement. The manufacturer can furnish a fuel control as an accessory to the muffler installations, and the complete installation is showing substantial fuel economies, as the fuel is shut off on deceleration. Accurate data on this phase of the operation is still being accumulated. Modified mufflers are being developed for passenger vehicles and small trucks.

This development may prove to be the answer to elimination of automotive vehicles as a source of smog.

PERFORMANCE *of a Flue-Fed* INCINERATOR*

E. R. KAISER, Senior Research Scientist, and **J. HALITSKY,** Research Scientist, College of Engineering, New York University; **M. B. JACOBS,** Director, Bureau of Laboratory, Department of Air Pollution Control, City of New York, and **L. C. McCABE,** Consultant and Project Director

THE flue-fed incinerator is a convenient means for the disposal and reduction of domestic rubbish and garbage in apartment buildings. A single flue and incinerator serve an entire building. The refuse is charged by the tenants through service doors connecting into the flue at each floor. The material accumulates in the furnace and is usually ignited by the janitor or attendant early in the morning. The products of combustion pass up the same flue and are discharged to the atmosphere at a suitable distance above the roof. A screened enclosure or spark arrester is commonly mounted on the top of the flue. Modifications of this simplest and commonest form are mentioned in the literature.[1]

Refuse is dropped at all times of day, whether a fire is burning or not, unless special arrangements are used to lock the service doors during periods of combustion.

Approximately 11,000 flue-fed incinerators are in use in New York City alone. They consume an estimated 600,000 tons of refuse annually. The reduction in bulk and weight of the residue greatly lessens the expense of collection and disposal by the city's Department of Sanitation.

The disadvantages of the conventional flue-fed incinerator are the emission of particles, unburned gases, smoke, and odor to the atmosphere.

Program and Objectives

Beginning Jan. 1, 1957, the U. S. Public Health Service made available to the Research Division of the College of Engineering, New York University, a research grant for the Control of Health Hazards and Air Pollution from flue-fed incinerators. The result is to be accomplished mainly by improving the combustion in the incinerator furnace in an economical manner.

The study is expected to serve as guidance to apartment owners and incinerator constructors, and for the enforcement of air-pollution control.

To provide a basis for comparison, the first portion of the test program was an investigation of the performance of an unmodified flue-fed incinerator, as normally operated in a modern 16-story apartment building. The incinerator selected was in daily operation in the Eton Building, one of a group of nine similar buildings owned by Fordham Hill Associates in the Bronx. The building has 128 apartments housing 260 adults and 39 children.

Because the tests were limited to one incinerator and are a minor part of the over-all program, the tests were by no means exhaustive.

In a later paper the authors plan to report on the performance of three identical incinerators that have been modified for better combustion and lower emission of contaminants to the atmosphere.

Eton Incinerator and Flue

As shown with internal dimensions in Fig. 1, the furnace was a simple refractory chamber with sloping brick hearth at the rear and a cast-iron grate at the front, the latter occupying 40 percent of the total plan area. Air for combustion was supplied by natural draft and controlled manually by dampers in the furnace and ashpit doors. Much air also entered the furnace by leakage around the doors and, particularly, around a sheet-iron cover over a 15-in.-diam opening in the front wall. This opening was originally provided with a barometric damper that had long since been discarded.

A 27 x 27-in. brick flue extended from the right-rear corner of the furnace roof a distance of 189 ft to a screen 43 ft above the roof. The coarse mesh of the screen retained pieces of paper and other light refuse above $^3/_8$ in. that were occasionally carried upward by the gases.

The service doors opening into the flue were located in closets on each of the 16 occupied floors of the building. Even when closed, the clearances around the doors permitted continuous air leakage into the flue. Even more leakage air entered the flue through louvers cast in the service door frames of the lower eight doors. The total opening of these louvers was 144 sq in. The leakage during tests was reduced slightly because the doors and frames on the first and 16th floors were replaced with tight plates to hold probes in the flue.

As it was not possible to account for all air ingress through the openings mentioned, some leakage undoubtedly occurred through the furnace setting and joints in the flue.

Refuse and the Incineration Cycle

The combustible portion of the apartment refuse was predominantly paper. Large cartons, gallon bottles, highly inflammable materials, and newspapers not used for wrapping garbage were not charged to the flue. About 80 lb of newspapers were collected daily and baled, but heavy cartons were flattened and charged through the furnace doors of the incinerator. Garbage consisted mainly of fruit rinds, coffee grounds, vegetable peelings, table scraps, fats, and bone. Sweepings, rags, and discarded clothing were a minor part of the incinerator charge.

It is therefore not far amiss to consider the reducible portion of the refuse as consisting essentially of cellulose (carbon and water), free moisture and a minor amount of combustible hydrogen combined with carbon in the fats. However, protein and sulfur in the charge, although minor in amount, have a significant effect on air pollution.

The noncombustible portion of the refuse is considerable and consists of glass bottles, tin cans, wire coat hangers, broken crockery, and discarded toys and knick-knacks. Together, these items are the major bulk of the residue.

Because of its heterogeneous nature and variable but obvious content, the refuse was not sampled for analysis. The carbon and hydrogen contents

* Presented at the Air Pollution Control Association, Annual Meeting, Sheraton Hotel, Philadelphia, Pa., May 25–28, 1958.

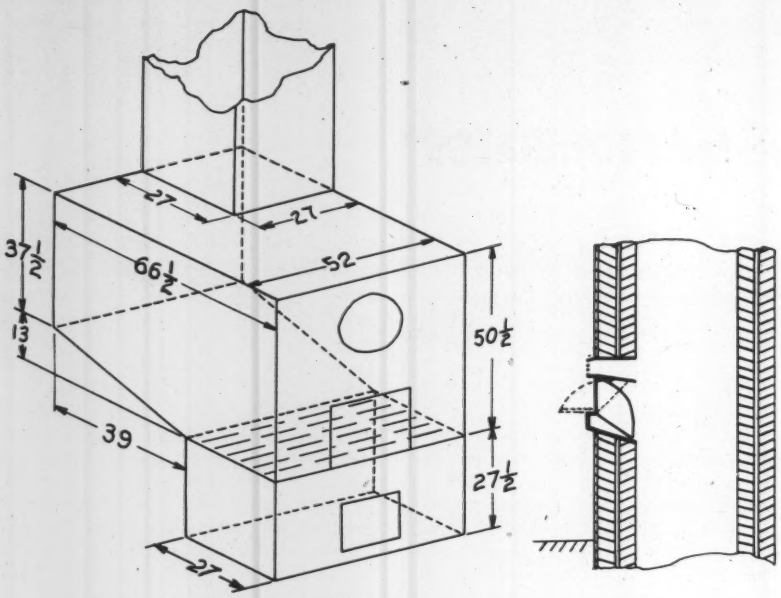


Fig. 1. Incinerator interior and cross section of flue and hopper door

could be closely approximated by the flue-gas analysis and gas quantities, as could the water content.

The daily cycle of refuse disposal to the incinerator is shown in Fig. 2. The timing and variation of the load causes the low load factor of the incinerator. Ample storage space is necessary in the incinerator as burning is restricted by law to the hours between 7 A.M. and 5 P.M., and the janitor's hours available to each building for incinerator operation are even fewer.

Under normal conditions the incinerator fire burns out by late afternoon. Refuse charged after that accumulates in the furnace. By 7 A.M. the following morning the refuse extends a short distance up the flue, sometimes up to the second-floor service door. The furnace is only partially filled. By hooking the accumulation under the flue and pulling it forward, the column in the flue descends, unless arching has occurred. In the latter instance, it is necessary to light the top of the charge in the flue.

Before a test, the charge was hooked forward to provide 10 in. of clearance height between the entrance to the flue and the top of the bed, leaving the top reasonably level. The refuse directly under the flue had been compacted by the impact of the refuse packages, while in the opposite corner and front zone the charge was largely uncompacted paper.

Normally, after three and a half to four hours of unattended combustion, during which the tenants drop additional refuse, the janitor returns to shovel out the more accessible bottles and tin cans near the furnace doors. The heavy mound of unconsumed refuse under the flue is then hooked forward over the grate to complete the combustion. The ashpit door is opened slightly for additional air. Within 15 to 30 min the charge has been reduced, after which the fire on the grate is quenched and the residue is removed from above and below the grate. Refuse at the rear may be left burning to kindle refuse charged during the rest of the day. The fire is relighted during the early afternoon when necessary to leave maximum furnace space for the overnight accumulation.

Test Apparatus and Procedures

Late in the afternoon before the day of a test, the furnace and ash pit were vacuum cleaned. In order to perform the tests in a uniform manner and also for weighing the amount of refuse charged to the flue, arrangements were made with the management and tenants to deposit the refuse in containers outside the locked service closets. After weighing, the test crew dropped the refuse from the service doors on the same floors from which the collections came. The amount of refuse charged was the normal amount that would have accumulated in the incinerator between the late afternoon burnout and the light-off early on the following morning.

At the end of a test, the residue was removed and the furnace and ash pit were again vacuum cleaned, all material being weighed and measured for volume. The residue was then sorted and screened to determine the weights of glass and metal, residue under $^1/_4$ in., and combustible residue over $^1/_4$ in.

To observe the fire without affecting the draft, one of the two firing doors was replaced with a transite door with observation window.

Inclined manometers were employed to measure the drafts in the ash pit, furnace, and incinerator room itself. Draft taps were also installed 7 ft from the base of the flue and 38 ft from the top of the flue.

Temperatures of the gases in the flue were measured with bare thermocouples in radiation shields, the locations being 7 ft from the base of the flue and 28 ft from the top. A thermocouple in a $^5/_{16}$-in. OD stainless-steel sleeve was placed in position in the furnace, 12 in. inside the front wall, 12 in. from the roof, and centrally between the side walls. Readings of dry-bulb and wet-bulb temperatures of the air were taken near points of ingress to the system.

Flue gas was sampled continuously from the center of the flue at 7 ft from the base and 28 ft from the top. The lower sampler was water cooled. Samples were collected uniformly with respect to time by continuously drawing from the sampler streams. The gas samples were collected over saturated salt solution for 15-min intervals during periods of rapid burning, and for intervals of 30 min during periods of slower burning. The samples were promptly analyzed by Orsat apparatus for carbon dioxide and occasionally oxygen. A special burette with expanded scale between 0 and 3 percent was used for most tests. The percentage of carbon monoxide was too low for Orsat determination.

Gas velocities in the center of the flue were measured by pitot-static tube and micromanometer 38 ft from the top of the flue. The range encountered was 3 to 21 fps, with peaks to 30 fps when the furnace door was opened for raking. Several traverses across the flue in different directions indicated that the average velocity for the area was 79 percent of the velocity at the probe.

Particulate matter in the flue gas was sampled isokinetically in the center of the flue near the pitot tube. A sharp-edged nozzle, $^1/_2$-in. diam, facing directly into the gas stream,

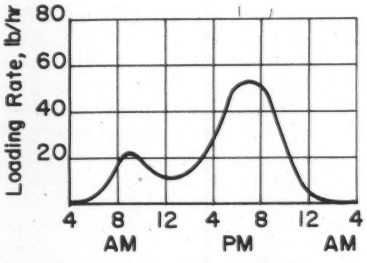


Fig. 2. Average hourly charging rates by tenants. Total of 430 lb, or 1.44 lb daily per tenant.

was attached to a stainless-steel tube leading to a filter thimble. The sampler was in operation from light-off through residue removal, but not during final furnace vacuuming. The rate of sampling was controlled frequently in accordance with the velocity determinations.

Figure 3 is a photograph of the dust-sampling train. The filtered flue gas was divided into equal streams, each of which passed through 250 ml of distilled water in Greenburg-Smith impingers. The impingers were immersed in ice baths to chill the gases so as to condense moisture, as well as to trap additional material not removed by the paper thimble.[2] A single dry impinger in the ice bath followed the wet impingers to trap moisture droplets. The temperature of the moisture-saturated flue gas was measured by a thermometer in the dry impinger.

The total volume of gas sampled for particulate matter was measured by a dry-type gas meter. A rotameter after the gas meter was used to control the instantaneous rate, after which the gases passed through a control valve to a central vacuum system. Corrections for meter pressure, meter temperature, and barometer were applied.

The volume of water in the impingers was measured before and after each test to aid in determining the water content of the flue gas. The difference in water contents of the flue gas and air was water from the distillation and combustion of the refuse.

At the end of each test the probe was brushed and washed out with distilled water. The wash water was combined with the impinger water and evaporated for total solids. The paper thimbles were brought to moisture equilibrium with a control thimble before weighing.[3]

The sampling and analysis of a number of noxious gases in the flue was conducted by the Bureau of Laboratory, Department of Air Pollution Control, City of New York. The methods used and an appropriate bibliography are given in a separate paper.[4] A freeze-out technique with temperatures down to minus 195°C was also employed to obtain samples for mass-spectrometer analysis. The presence of a number of hydrocarbon gases was established, with indications of their approximate proportions. A complete evaluation would be a major undertaking in itself, but it is believed that the total of unburned gases varies roughly in proportion to those investigated, as the combustion of all organic compounds is influenced by the same combustion factors, time, temperature, turbulence, and oxygen.

Smoke was measured by light absorption of a 24-in. column of flue gas that was withdrawn continuously from the flue 48 ft from the top. A photograph of the smoke meter is shown in Fig. 4. The smoke was also observed from the roof on occasion and was white to light gray.

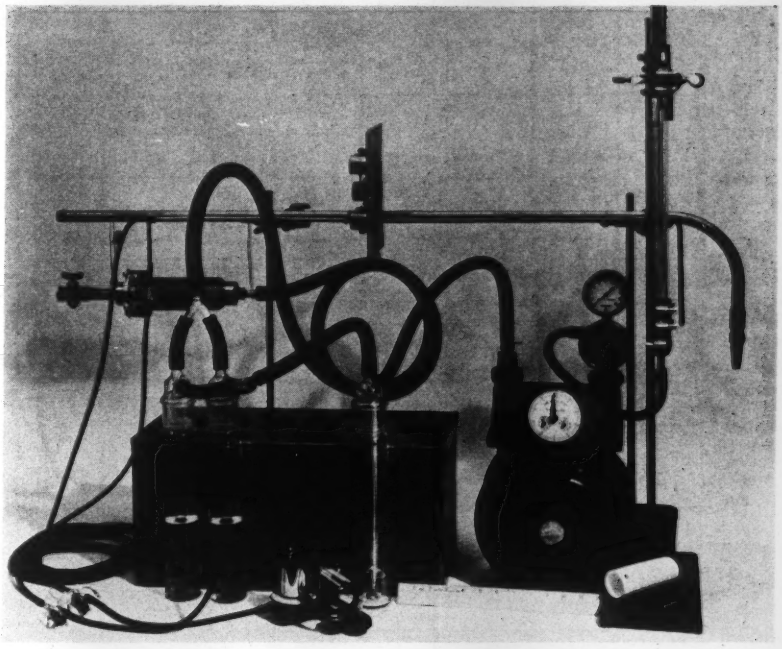


Fig. 3. Dust sampling train and pitot-static apparatus.

The odor intensity of the flue gas was evaluated by one and the same observer according to the ASTM Method D 1391 – 56 T.[5] A sample of about 400 ml was collected over mercury by steady withdrawal from the upper flue-gas sampling line during the period of test. By systematic dilution of the gas and by sniffing, the concentration of flue gas in odor-free air was found at which the odor was barely perceptible (threshold).

Conditions of Test

Six tests with normal apartment-house refuse were run under a variety of typical conditions, as tabulated below. The distinguishing features of the tests are summarized as follows:

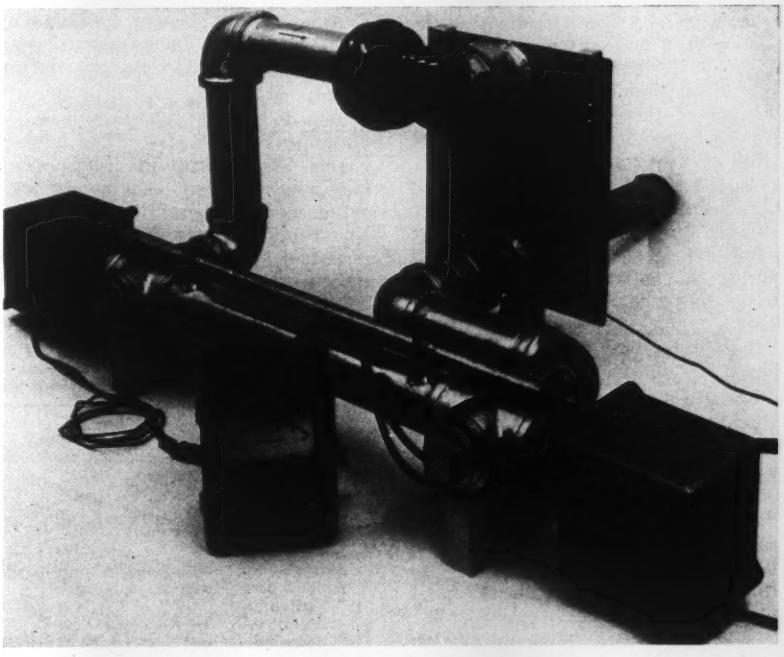


Fig. 4. Smoke meter. Photocell is at left; light source is at right. The fan circulated flue gas through the column and returned it to the flue.

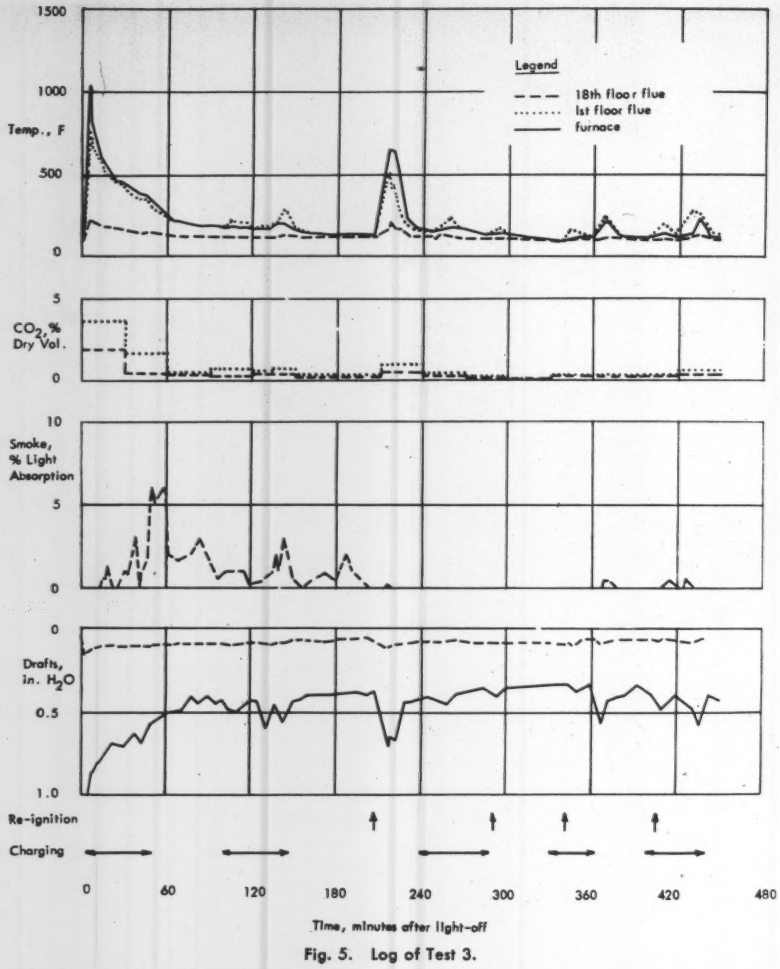


Fig. 5. Log of Test 3.

Tests 1 and 2 were essentially duplicates of the fast early-morning burndown of the overnight accumulation. Test 2 was terminated in shorter time because of the faster burnout made possible by more complete raking of the refuse over the grate.

Test 3 was the fast early-morning burndown followed by the slower burning during the remainder of the day. Refuse was charged at intervals during the entire test. Fig. 5 illustrates the combustion performance of Test 3.

Test 4 was the fast early-morning burndown with the vents on the service doors sealed. Such vents are usually absent in flue-fed incinerator installations. The air ingress to the furnace was controlled to the normal amounts of the other tests by reducing the damper openings in the furnace and ashpit doors. The combustion conditions were therefore comparable to those of Tests 1 and 2 and the first part of Test 3.

Test 5 began with a minimum amount of refuse burning in the furnace. Additional refuse was added from time to time as was normal for mid-day operation. The vents were sealed and the dampers were left the same as for Test 4.

Test 6 was a fast early-morning burndown with a heavy incinerator charge. The furnace and ashpit openings were increased, and the fire was raked more frequently to reduce the time required for burnout. The rate of operation was faster than for all prior tests and was probably the maximum rate possible, as indicated by some carry-up of paper which partially plugged the screen. *(See Table I)*

Results

As the purpose of the incinerator was to reduce the weight and volume of the refuse, the effectiveness can be judged from Tables II and III. Data were obtained in four of the six tests.

The average weight of residue was 37 percent of the charge. The average bulk density of the residue as shoveled into ash cans was not determined until Test 6. The results of that test and four later tests not reported indicate an average value of 15.4 lb/cu ft for the residue. As the average bulk density of the charges was 4.1 lb/cu ft, the volume occupied by the residue was less than one tenth (9.3 percent) of the volume of charge.

Based on analyses, the residue consisted of the approximate composition shown in Table III.

Tables IV and V provide a summary of the temperatures and drafts. The highest furnace and flue temperatures as well as drafts, were recorded on the faster burns. The flue gas had cooled considerably by loss of heat to the brick and by dilution with leakage air by the time it reached the upper test probes.

Because of the large cast-iron grate with 40 percent grate opening and loose refuse over the grate, the resistance to air was low. The ashpit drafts were practically indentical with the furnace drafts.

The drafts were ample at all times. To restrict the velocities through the furnace, it was necessary to keep the door to the incinerator room closed, especially when hooking and cleaning the fire.

The quantities of air to the furnace shown in Table VI were many times higher on each test than was necessary for combustion. The high excess of air increased the velocities in the flue and undoubtedly caused higher emissions of dust than would have prevailed otherwise. The air rates and proportions were calculated from velocities measured 38 ft from the top of the flue (above last opening) and the CO_2 contents of the flue gas measured before and after admission of dilution air through the service doors and vents. *(See Table VII)*

Table I—Conditions of Test

Items and Locations	Test No. 1	2	3	4	5	6
Total charge, lb	275[a]	276	410	262	124	316
Load at start, lb	275[a]	276	297	262	20	316
Volume of charge, cu ft	64	53	75	75	—	87
Bulk density, lb per cu ft	4.3	5.2	4.0	3.5	—	3.6
Duration, hr	2.25	2.0	7.5	1.5	2.0	1.25
Service-door vents	Open	Open	Open	Sealed	Sealed	Open
Area of damper openings, sq in.						
Firing door	2.6	2.6	2.6	1.3	1.3	5.2
Ashpit door	5.2	5.2	5.2	2.6	2.6	32.5
Ashpit door open last 15–30 min	23.4	23.4	No	23.4	No	—

[a] Based on combustion calculations.

Table II—Residue Weights, Lb

Items	Test No. 1	2	3	6
Metal and glass	67.0	75.5	82.0	62.0
Other residue, over 1/4 in.	23.8	24.8	39.5	22.5
Fine residue, under 1/4 in.	22.0	14.7	23.7	14.7
Total, lb	112.8	115.0	145.2	99.2
Residue weight, in percent of charge	41	42	35	31
Bulk density of residue, lb/cu ft	—	—	—	14.9

Table III—Composition of Residue, Percent by Weight

Components	Test No. 1	2	3	6	Avg
Moisture[a]	5	8	11	7	8
Combustible (carbon)	17	15	17	17	16
Metal and glass (+1/4 in.)	65	68	61	62	64
Ash	13	9	11	14	12
Total	100	100	100	100	100

[a] Corrected for quench spray.

Emissions to the Atmosphere

The four criteria that were used in this study for evaluating atmospheric pollutants from the flue-fed incinerator were the quantities of particulate matter, noxious gases, smoke, and odor produced. The particulate matter collected included fly ash, soot, particles of charred refuse, tar droplets, and other aerosols that were either trapped in the paper thimble, or trapped or condensed in the chilled, wet impingers. The more volatile liquids condensed in the impinger were distilled off with the water on subsequent evaporation for solids.

The emissions of particulate matter and selected noxious gases are reported in Table VIII.

The mass-spectrographic analyses indicated that methane, ethylene, acetaldehyde, methyl alcohol, ethyl alcohol, propylene, and acetone were present. Larger amounts of aromatics, lower hydrocarbons, and other organic compounds were present but not identified. Preliminary calculations indicate that these compounds total over 0.6 lb/100 lb refuse in addition to those given in Table VIII.

Smoke was evaluated by the Beer-Lambert equation, assuming smoke particles of the same size and light absorption, varying only in concentration:

$$c = k \log I_0/I$$

where c is concentration of smoke particles per unit volume of gas, k is a constant, I_0 is the original intensity of the light, and I is the intensity of the light transmitted through the smoke. One standard cubic foot of flue gas having a smoke density equal to a light absorption of 20 percent in a 2-ft column was rated one smoke unit.

The total smoke for each test was determined by integrating the smoke concentrations with the corresponding increments of flue-gas volume, and totaling. The results tabulated in Table IX are quantitative within the limits of the above assumptions.

The periods of smoke emission occurred typically after the furnace temperatures had fallen into the 500–300°F range following a period of rapid burning. Smoking ceased after the furnace had cooled to 300°F although burning and distillation were still continuing. Hooking the fire after the first hour of operation caused the temperature-burning-smoking cycle to repeat, but with less smoke. Furnace temperatures above 500°F apparently insured ignition of the organic products volatilized from the charge, but the evolution of such compounds diminished to a low level at furnace temperatures under 300°F.

During the slow burning of Test 5, the smoke was negligible because the furnace temperatures fluctuated around an average of only 317°F. The low total of smoke in Test 3 was the result of a long period of slow burning which followed a typical fast burn. Smoke in Test 6 was minor because of a hot, fast fire. The higher values of smoke in Tests 1, 2, and 4 appear to have been caused by sustained periods of the critical furnace temperature (300–500°F) caused by medium rates of burning.

The results of the odor evaluations were likewise based on concentrations and volumes of flue gas, as summarized in Table X. An odor unit per cubic foot of 1.0 represents gas whose odor is barely perceptible. A gas of 2.0 odor units per cubic foot would have to be diluted with an equal volume of odor-free air to be barely perceptible, etc. The number of volumes of outside air that must mix with each volume of the flue gas before the odor is perceptible is one less than the odor units per cubic foot.

It is understandable why gases in this range of odor concentration would be detectable at open windows on upper floors of the same or adjoining buildings. The odor of the gases may be described as "sweetish" and "burnt."

While there does not appear to be good correlation between degree of odor intensity and total amounts of noxious substances, there does appear to be fair correlation between odor intensity and aldehyde concentration. The latter are often unpleasant smelling compounds.

The temperatures in the furnace

Table IV—Temperatures, °F

Items and Locations	Test No. 1	2	3	4	5	6
Outside air	46	39	36	43	47	36
Combustion air	80	74	78	73	75	72
Furnace						
Max	1300	970	1035	1350	450	1200
Avg	470	463	305	668	317	530
Flue gas, 7 ft from base of flue						
Max	1080	1020	760	890	410	1700
Avg	391	429	280	446	256	531
Flue gas, 28 ft from top of flue						
Max	182	148	238	294	166	425
Avg	129	130	139	180	140	216

Table V—Drafts Relative to Outside Air, in Inches of Water

Items and Locations	Test No. 1	2	3	4	5	6
Incinerator Room						
Max	0.1	0.2	0.3	0.4	0.3	0.2
Avg	0.1	0.15	0.2	0.3	0.2	0.2
Furnace						
Max	0.70	0.73	1.04	1.50	0.82	1.50
Avg	0.49	0.54	0.53	0.87	0.61	0.82
Flue, 7 ft from base						
Max	n. d.[a]	0.70	1.02	1.46	0.82	1.50
Avg	n. d.	0.51	0.52	0.86	0.61	0.79
Flue, 38 ft from top						
Max	0.13	0.15	0.15	0.21	0.11	0.20
Avg	0.10	0.11	0.09	0.13	0.09	0.11

[a] n. d.—not determined.

above the burning refuse were usually well below the 1500°F deemed necessary to complete the oxidation of odorous compounds.[6]

Over-all Evaluation

In an effort to correlate the several tests, a tabulation of ratings is given in Table XI below: The lowest emission per 100 lb refuse was rated 1, next lowest 2, etc. The lowest air rate in pound per hour through the furnace was rated 1, second lowest 2, etc., while the lowest rate of burning in pound per hour was also rated 1, next lowest 2, etc.

Only partial correlation is evident from the table. Test 6 had the fastest burning rate and highest air rate to the furnace. The emission of particulates was the highest, as might be expected, and smoke was low. Tests 3 and 5 were low in burning rates and air rates, and the emissions were medium to low, with a low total. Test 4 was low in emission of particulates and noxious gases despite having the second highest burning and air rate.

A negative correlation is evident between odor and noxious gases, which is contrary to expectations. Smoke and noxious gases do not correlate. It appears on the basis of the over-all results that the slow burning of refuse in a cool furnace, with charging during burning, causes lower emissions than fast burning without charging during burning but this requires additional study.

Tests 1, 2, and 4 were conducted under comparable conditions of air supply to the furnace, but the emissions were quite different.

The variation in composition of the charges is unknown. This factor may account for the lack of better correlation between similar tests. The tests were deliberately undertaken to study field conditions rather than to test with standardized charges, such as would be advisable for research on incineration factors.

One aspect of the observed emissions which has not been sufficiently evaluated is the significance of the smoke readings. Since light beams are scattered by any particulate matter in the micron range, it is conceivable that the meter was responding to a fog of liquid droplets rather than dust. This possibility must be considered in view of the observed character of smoke using equipment described in Reference 7, recorder tests made by the New York City Department of Air Pollution Control Laboratory simultaneously with the smoke meter. The maximum grayness of trace occurred when the light-meter readings approached zero, and the maximum light reduction was obtained when the spots assumed a yellowish color.

Table VI—Dry Air Entering Incinerator and Flue, Lb and Percent

Item	Test No. 1	2	3	4	5	6
To furnace (% of total air)	8,440 (43)	6,310 (40)	25,400 (55)	6730 (69)	6,140 (57)	6,480 (45)
Infiltration to flue (% of total air)	11,270 (57)	9,490 (60)	20,800 (45)	3070 (31)	4,610 (43)	7,900 (55)
Total, lb	19,710	15,800	46,200	9800	10,750	14,380
Furnace air, lb per 100 lb refuse	3,070	2,290	6,200	2570	4,950	2,050
Furnace air, lb per hr	3,750	3,160	3,390	4490	3,070	5,190

Table VII—Flue Gas Weights and CO_2 Contents

Item	Test No. 1	2	3	4	5	6
Flue gas						
Wet, Scf[a] × 1000	268	214	626	135	147	197
Dry, Scf × 1000	263	211	618	131	144	193
Wet, lb	19,980	16,050	46,660	10,040	10,910	14,600
CO_2 content, av % dry vol.						
Leaving furnace	1.09	1.68	0.90	1.89	1.10	2.09
Upper flue	0.47	0.67	0.50	1.30	0.63	0.95

[a] Scf—standard cubic foot at 70°F and 29.92 Hg.

Table VIII—Emissions to Atmosphere from Flue Gas

Items	Test No. 1	2	3	4	5	6
Particulate Matter						
Lb for test	2.33	4.27	5.42	2.73	1.52	4.88
Lb per 100 lb refuse	0.85	1.55	1.32	1.04	1.23	1.54
Lb per 1000 lb flue gas	0.117	0.266	0.116	0.272	0.139	0.334
Grains per Scf flue gas	0.061	0.140	0.061	0.142	0.072	0.173
Lb per 1000 lb furnace gas corr. at 12% CO_2	2.98	4.69	2.81	2.50	2.64	4.18
Noxious Gases, lb						
Aldehydes, as formaldehyde	0.50	0.36	0.52	0.86	0.28	1.23
Ammonia	0.04	0.09	0.01	0.04	0.03	0.03
Benzene	0.03	0.01	0.00	0.00	0.00	n. d.
Esters	n. d.	0.58	0.98	0.15	0.15	6.13
Nitrogen oxides, as NO_2	0.01	0.01	0.01	0.01	0.01	0.02
Organic acids, as acetic	5.53	1.90	2.59	1.30	1.23	2.10
Phenols, as phenol	0.01	0.01	0.01	n. d.	0.01	n. d.
Sulfur dioxide	0.13	0.07	0.03	0.01	0.02	0.00
Total for test, lb	6.25+	3.03	4.15	2.37+	1.73	9.51+
Lb per 100 lb refuse	2.28+	1.10	1.01	0.91+	1.40	3.01+
Carbon monoxide, lb per 100 lb refuse	n. d.	1.69	1.10	1.50	1.29	1.13

Table IX—Smoke Quantities

Smoke Units	Test No. 1	2	3	4	5	6
Total for test	12,230	4790	3330	3460	80	1460
Per 100 lb refuse	4,450	1740	810	1320	65	460

Summary and Conclusions

The investigation reported is a limited survey of representative modes of operation and results of one flue-fed incinerator. The tests were conducted to serve as a basis for comparison with future tests on identical incinerators with modifications to improve combustion and reduce air pollution.

1. The incinerated refuse from a 128-apartment building (299 occupants) was approximately 430 lb a day, an average of 1.44 lb per day per occupant. Had all the newspaper been burned, the per capita daily incinerator charge would have been 1.7 lb.

2. The flue-fed incinerator reduced the apartment refuse to about 37 percent of its original weight and to about 10 percent of its original volume. The bulk density of the refuse averaged 4.1 lb/cu ft in the incinerator. The residue had a bulk density of 15.4 lb/cu ft in the ash cans.

3. The incinerator was too small for the overnight accumulation of refuse. A more central location of the flue in the furnace roof would have utilized the furnace volume more fully and would have reduced the manual attention necessary.

4. The residue averaged 64 percent metal and glass over 1/4 in., 12 percent ash, 16 percent combustible, and 8 percent moisture, excluding quench water.

5. The air normally supplied to the furnace was 10 to 20 times the the-

oretical air necessary for complete combustion. The high excess air reduced the furnace temperatures and undoubtedly affected adversely the combustion of volatile matter and emission of fly ash.

6. The infiltration air entering the flue through vents on the service doors and cracks averaged 35 percent more than entered the furnace. Sealing the vents reduced the infiltration air to the flue to 45 percent of the furnace air during the period of fast burning.

7. The peak furnace temperatures measured by the thermocouple in the gas space, 12 in. from the front wall and roof, varied from 970 to 1200°F during the rapid periods of burning. The average furnace temperatures during the same tests ranged from 668 to 463°F. Such temperatures are lower than necessary to complete the burning of organic compounds volatilized from the refuse. During periods of slow burning, which are sustained by small charges of refuse after the morning burn, the furnace temperatures are even lower.

8. The emissions of particulate matter to the atmosphere via the flue gases ranged from 0.85 to 1.55 percent of the refuse weight. The weights of particulate matter ranged from 2.5 to 4.7 lb/1000 lb of furnace gas corrected to 12 percent CO_2.

9. The emissions of eight noxious gases totaled 0.9 to 3.0 lb/100 lb refuse. The presence of additional unburned hydrocarbons in the flue gases was confirmed by mass-spectrometer tests.

10. Emissions of light gray to white smoke were observed during periods of the tests. The smoke units ranged from 65 to 4450/100 lb refuse, each smoke unit being equivalent to a cubic foot of flue gas having a light absorption of 20 percent in a 24-in. column. The maximum smoke intensity observed was 24 percent light absorption.

11. The average odor concentrations ranged from 2.5 to 100 ASTM odor units. To reduce the odor to the threshold of perception would require corresponding dilutions of one volume of flue gas with 1.5 to 99 volumes of odor-free air. Per 100 lb of refuse charged to the incinerator the total odor units (concentration × cubic foot of flue gas) ranged from 5,000,000 to 240,000 or a variation of over 20 to 1.

12. The incinerator had inherent features of design and operation that caused high emissions of particulate matter and unburned organic compounds. The necessary hooking of the charge during burning caused rapid emission of volatile products, because raw refuse was mixed with incandescent material. During hooking a high velocity occurred over the fire because of the open firing doors. Opening the ashpit door after hooking increased the velocities through the bed and undoubtedly caused carryover of dust. The removal of residue by shovel also stirred up dust, some of which undoubtedly escaped up the flue.

13. The charging of refuse during burning could contribute to the discharge of particulate matter. Sweepings and other light material should be bagged or wrapped before dropping, and preferably charged at times of low flue velocities, such as when the fire is low or out.

14. Suggested modifications to the conventional incinerator include (*a*) control of the furnace air supply, (*b*) better mixing of air and volatile products from the burning refuse in a zone of high temperature, (*c*) new furnace designs to eliminate the necessity for hooking and raking the refuse and residue, and (*d*) residue removal with minimum air flow.

15. Development of new and automatic types of flue-fed incinerators should be considered along with possible improvements by modification of existing types. Both of these approaches should be directed towards better control of the combustion process and removal of dust from the flue gases.

Table X—Odor Concentrations and Total Odor Units

	Test No.					
	1	2	3	4	5	6
Odor units per cu ft	2.5	14	5	100	8	n. d.
Dry flue gas, Scf × 1000	263	211	618	131	144	193
Total odor units × 1000	657	2950	3090	13,100	1150	—
Odor units × 1000 per 100 lb refuse	240	1070	755	5,000	930	—

Table XI—Evaluation of Performance

Rates of Operation, and Emissions per 100 Lb Refuse	Test No.					
	1	2	3	4	5	6
Burning rates (lowest = 1), lb/hr	3	4	1	5	2	6
Furnace air (lowest = 1), lb/hr	4	2	3	5	1	6
Emissions (lowest = 1) per 100 lb refuse						
Particulates	1	6	4	2	3	5
Noxious gases	5	3	2	1	4	6
Odor	1	4	2	5	3	n. d.
Smoke	6	5	3	4	1	2
Total rating	13	18	11	12	11	13+

Acknowledgment

The authors wish to express their appreciation to the organizations that supported the project with facilities and funds, and those who participated in the tests.

This investigation was supported by a research grant (S-53) from the National Institutes of Health, U. S. Public Health Service. Equipment was provided by the New York University. The Fordham Hill Associates and staff co-operated fully in the use of the incinerator and other facilities in their Eton Building.

M. M. Braverman, S. Hochheiser, I. Ettinger, C. Theophil, and B. H. Pearson of the Bureau of Laboratory, New York City Department of Air Pollution Control, conducted the sampling of and determination of noxious gases. Donald Yee and Vincent Henry of the N.Y.U. Chemical Engineering Department investigated the hydrocarbon gases by mass spectrometer.

Robert Fatell, senior research aide, Mrs. Sylvia Friedman, research aide, and Irving Karmin, associate research scientist, assisted in fabricating equipment, conducting tests, and in calculating the results.

The encouragement and advice of Dr. Harold K. Work, Director, Research Division of the College of Engineering, and of Commissioner Leonard Greenburg, Deputy Commissioner Sylvan Hanauer, and Chief Engineer Leo P. Flood of the Department of Air Pollution Control deserve special mention.

REFERENCES

1. Paul L. Magill, Francis R. Holden, and Charles Ackley, *Air Pollution Handbook*, McGraw-Hill Book Co., Inc., Chapt. 13, pp. 12–13 (1956).
2. Carl V. Kanter, Robert G. Lunche, and Albert P. Fudurich, "Techniques of Testing for Air Contaminants from Combustion Sources," *Air Pollution Control Assn. Annual Meeting Paper No. 56-25* (1956).
3. Western Precipitation Corp., "Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases," Bulletin WP-50, 5th edition (1956).
4. M. B. Jacobs, M. M. Braverman, S. Hochheiser, and I. Ettinger, "Sampling and Analysis of Incinerator Flue Gases," *Air Pollution Control Assn. Annual Meeting Paper No. 58-7* (May, 1958).
5. American Society for Testing Materials, "Tentative Method of Test for Odor Concentration in Air and Gases (Dilution Method)," D 1391 – 56 T.
6. Reference 1, Chapt. 13, p. 26.
7. I. Ettinger, M. M. Braverman, and M. B. Jacobs, "The Use of the Von Brand Filtering Recorder in the Evaluation of Incinerator and Smoke Abatement Devices," J. Air Pollution Control Assn., **8**, 120–123 (August 1958).

ABSTRACTS of Recent LEGAL DECISIONS Relating to Air Pollution

LEGAL COMMITTEE, William Foster, Chairman, Air Pollution Control Association

***Commerce Oil Refining Corp. v. Miner et al.*, _____ Federal Supplement _____ (District Court, R. I., Jan. 5, 1959)**

ACTION: Trial proceeded based on defendant's counterclaim for a declatory judgment and an injunction in which it was alleged that certain amendments to the zoning and building ordinances were invalid and that the crude oil refinery to be erected by Commerce would, after completion, constitute a nuisance. The original complaint by Commerce was for an injunction against residents harassing construction efforts and for damages. At the trial Commerce announced in court that it would put in no evidence in support of its complaint. The complaint was then dismissed.

FACTS: Commerce had acquired a license to erect a refinery in Jamestown on a residential and resort island in Narragansett Bay where there were no industries theretofore. Jamestown ordinances had required permits for all buildings and expressly banned refineries, but a 1956 amendment withdrew oil refineries from these requirements and prohibitions. This amendment followed a vote by the townspeople in favor of the refinery. The plant would include 15 stacks from 20 to 200 ft in height, and expected to process about 43,000 bbl of Kuwait oil each day by fractional distillation, catalytic cracking, and polymerization. In the process hydrogen sulfide, sulfur dioxide, and mercaptans would be produced.

Engineering plans called for the use of the most modern sulfur removal and other control equipment, but 37 tons of SO_2 were expected to be discharged daily, and over 100,000 gal of water pumped from the bay would be used for cooling, washing, and hydrocarbon removal. There was conflicting testimony on ground concentrations of SO_2. The refinery would require illumination at night.

HELD: 1. The amendments to the ordinance are invalid because specifically exempting oil refineries was itself a regulation. Regulation is only permitted as an exercise of the police power. Because a refinery is a potential source of danger, and the record did not disclose that proper restrictions were imposed on the operation of this refinery, there was no ground for finding the exempting ordinance conducive to the conservation of the "public health, safety, and welfare" of Jamestown. Unless a regulation has some such substantial relationship, it is an unauthorized exercise of police power.

2. The license was held invalid, despite the fact that the enabling act and the ordinance both provided that the Town Council could license a refinery. Its invalidity arose out of the fact that refineries were permitted by the ordinance only if certain extensive operational and structural specifications were met. The court found that these amounted to establishment of a building code, which codes were covered by a different enabling statute. The building code enabling statute required notice and a hearing which was not had for the "licensing" ordinance. The entire municipal ordinance relating to crude petroleum refineries was thus invalid as was the license issued thereunder.

3. The proposed refinery operation was enjoinable as a nuisance, because the expert testimony of the counter claimants indicated that odors from H_2S and SO_2 would be easily detectable at defendants' properties from two-thirds of a mile to four miles away. The court considered evidence of prevailing winds and wind velocities, the location of residential property with respect to the proposed plant, the effectiveness of devices for preventing odors and air pollution and the facets of refinery operation likely to result in nuisance-type emissions. The Town Council did not have the benefit of detailed expert testimony when it issued the licenses, though the court found it necessary to reject testimony submitted by Commerce. The court found that obnoxious gases would inevitably escape and be carried by the prevailing winds to defendants' properties.

4. In order for an anticipated nuisance to be enjoinable, Rhode Island law required that defendants show that it was practically certain that their property value and the enjoyment thereof would be specially reduced. Here they had made such a showing. The fact that the refinery might contribute to the economic welfare of the town is not determinative. The operation of the refinery in the manner and at the location proposed would constitute a nuisance. Injunction granted.

***Huron Portland Cement Co. v. Detroit* 93 N. W. 2d 888 (Mich., Jan. 12, 1959)**

ACTION: Injunction to restrain city from prosecuting for violation of "Detroit Smoke Abatement Code."

FACTS: The Detroit code made unlawful the emission of smoke greater in density than Ringelmann No. 2. If there were more than three warnings of violations in a 12-month period, the offending equipment could be sealed. Steamships owned by Huron were cited for violations.

PLAINTIFF'S CONTENTIONS: The ordinance is unconstitutional as applied to Huron unless limited to smoke caused by improper firing or by improper use of equipment. Further, state or local regulation of interstate commerce is unconstitutional in this case, because Congress has pre-empted this field in its provisions for controlling and inspecting Great Lakes vessels.

TRIAL COURT: Held ordinance constitutional and a necessary and reasonable exercise of the police power.

Michigan Supreme Court HELD: 1. Congress has not pre-empted the control of smoke on interstate vessels nor has it enacted legislation designed to protect persons and property on land.

2. This ordinance is directed at the prevention of air pollution, not at regulating interstate commerce. Any regulatory effect on such commerce is indirect and incidental.

3. The fact that Congress had appropriated $5,000,000 in 1955 for air pollution research on a local level indicates Congressional blessing and encouragement of air pollution control by local authorities.

4. Not all regulation would be upheld, but only such regulation as is reasonable. City dwellers must acclimate themselves to some smoke, but

an ordinance such as this designed to outlaw smoke of such density as to be readily preventable is a reasonable exercise of the police power.

5. Conceding that an interstate carrier serving many points might be subject to the provisions of the strictest regulation of any point it serves and be required to install equipment necessary to meet them, the question of whether this is unreasonably burdensome will not be decided in a case where the ordinance before the court is found reasonable.

6. It would be desirable to have uniform legislation of federal scope, but in absence of such legislation local governments may protect citizens from unreasonable air pollution. Injunction denied.

Baker v. Thompson-Heyward Chemical Company, 316 S. W. 2d 652 (Mo. App. Oct. 6, 1958)

ACTION: Damages for personal injuries.

FACTS: Plaintiff alleged that he received injury to his throat, lungs, chest, skin, and body when the defendant negligently emitted a heavy fog of noxious and poisonous gas from its plant. The defendant was engaged in the business of bottling chlorine gas but on the day in question, a Sunday, the plant was not in operation. Plaintiff stated that while walking by the plant he heard two explosions, saw a cloud of gas escape and attempted to get away from the plant but breathed some gas while fleeing. The case was tried on a *res ipsa loquitur* theory.

TRIAL COURT: Verdict and judgment of $3200 for plaintiff.

Kansas City Court of Appeals—Affirmed, HOLDING: 1. Jury properly instructed that if explosion and cloud of gas occurred, injury resulted, "and if you find that defendant failed to use ordinary care to avoid said explosion and said eruption of gas, if so, and was thereby negligent, if you so find, then your verdict must be for the plaintiff, . . ." in a case tried on *res ipsa loquitur* theory. Instruction not defective for giving jury "a roving commission to find negligence." In a *res ipsa* case some negligence may be shown by circumstantial evidence. It would have been proper to instruct a jury that a finding of an explosion and the ensuing cloud of gas warranted a finding of negligence without more.

2. ". . . the release of a poisonous gas at a place where people are or have the right to be, would create a defective and unsafe condition as a matter of law. Under such circumstances . . . it is not a factual issue."

SUMMARY: In a *res ipsa* case, a showing that there was an explosion followed by a cloud of irritating gas was sufficient basis for a finding of negligence and releasing poisonous gas in an area where people had a right to be constituted the creation of an unsafe condition *as a matter of law*.

ENGINEERING *and Maintaining* IN-PLANT *Air Pollution* CONTROL*

O. C. THOMPSON, Union Carbide Chemicals Co., South Charleston, W. Va.

Plant Organization for Air Pollution Control

Each company, and perhaps each plant of a company, can be expected to have differences in their approach toward air pollution control. This is only natural since there are wide organizational differences between companies, and often between different plants of the same company.

Organization for air pollution control will vary. It may be set up as a staff function, as a line responsibility, or a combination of both. It can be expected to vary depending upon size of plant, type of operation, location, general attitude of the community toward industrial operations, the legislative situation with respect to air pollution control, and so on.

Elements for Successful Plant Pollution Control

The organization and programming for air pollution control begins with a clearly understood company policy. Written policy statements seem the exception rather than the rule.

Union Carbide Chemicals, with seven plants in five states, has a five-step written policy specifically covering process wastes and related community relations, as follows:

1. Design Engineering Departments are responsible for incorporating into the design of any new installations the means for disposal of all process wastes with a minimum of disturbance to the plant community.
2. Each operating plant will assign to some individual the responsibility for proper disposal of process wastes.
3. Each operating plant will assign engineering and laboratory talent for continuing studies of waste disposal.
4. Each operating plant will take an active part in any local committee groups or branches of agencies or trade associations interested in industrial waste disposal.
5. Each operating plant will assign to some individual the responsibility of representing the company to the public on all matters pertaining to air or water waste disposal.

This written policy has proved to be of great value. It puts the responsibility for plant wastes control squarely where it belongs—on the plant management. It does something else of great value. It makes clear that control of wastes begins with product research and development in the laboratories, and that this control is extended through engineering, and the design and construction of each plant unit. It is the means by which consideration is assured for waste control in the work of the four departments having company-wide responsibilities. These are Research, Development, Engineering, and Design and Construction.

So much for the over-all concept and policy with respect to the control of wastes. What about the technical problems involved in air pollution control?

An enormous volume of technical knowledge has been published on the many aspects of air pollution. Universities, foundations, consulting services, industrial companies, trade associations, and other agencies including all levels of government are now engaging in development and research on air pollution. The outpouring of published papers has become so great that bibliographies of newly published work are now issued on a regularly scheduled basis.[1]

Much valuable information on the various aspects of air pollution can be obtained from such publications as the Air Pollution Abatement Manual of the Manufacturing Chemists' Association[2] and the Air Pollution section of the manual issued by the American Petroleum Institute.[3] The Air Pollution Handbook[4] includes chapters on meteorology, sources, instrumentation, equipment, and other aspects of air pollution. All this outpouring of technical data is of value to the design engineer and the air pollution control official.

Now how can all this technical knowledge be organized and put to work? A search was made through a bulging bookcase of published papers, proceedings of numerous conferences, and textbooks on air pollution. One of the few items found in this search that did supply such information was a recently published magazine article.[5] This article was entitled "Industrial Air Pollution" and was written by William G. Christy. It was published in the September-October, 1958 issue of *Industrial Wastes*. Although the exact application may vary in different plants, the counsel given in this article on the organization and operation for air pollution control could be of practical value to any plant faced with this difficult problem.

The following steps are recommended for the organization and operation of plant air pollution control.

Place Responsibility

A qualified individual should be given the responsibility of wastes control of the plant. This may be limited to emissions to the air or may include all processing wastes of whatever nature.

Form a Committee

In some large plants with many production units of varying type, the forming of a committee has been found to be a successful means for arousing interest in and developing the practices necessary for wastes or pollution control. Usually a representative of each major department is designated for such a committee.

Assign Inspectors

These are often plant guards, watchmen, or other employees whose duties require them to frequently move about the plant. Such inspectors should watch for and promptly report any excessive emissions.

Evaluate Your Problem

A beginning of this evaluation could be an inventory of emissions. For this a questionnaire, to be completed by the head of each department or processing unit, has been found useful. (See appendix for a sample copy.)

---

* Presented at the Tenth National Plant Maintenance and Engineering Conference, Cleveland, Ohio, Jan. 26–28, 1959.

Once the inventory is completed the evaluation process can begin. A wide range of treatment can be expected. These may include engineering studies resulting in redesign or replacement of equipment, intensive campaigning for better "housekeeping," comprehensive plans for an educational program, and so on.

Inform Your People

Recently a sanitary-engineer member of a state water pollution control board offered a suggestion. He thought that since the problem of plant water pollution control was comparable to the never-ending efforts to improve employee safety, the same methods for "selling" it to plant personnel could be used. The same can be said of plant air pollution control. Just as is done in many plants in carrying out the safety program, the use of posters, articles in plant bulletins, group training in proper operation and maintenance—all these things are applicable for plant air pollution control.

Keep Active

This may seem an unnecessary admonishment. Yet all of us have seen fine programs started with much enthusiasm generated, only to soon "run out of gas." Careful planning may prevent such failures—if only attainable objectives are set—if the working group is imbued with the necessity of cleaning up and keeping clean. In other words, if air pollution control is made one of the normal functions of plant operation and maintenance, the program need not fail.

Experience has proved the value of certain beyond-the-plant activities. Three of these are added to our list as deserving of consideration.

Co-operate with Other Industries in the Area

This may include active representation in a local chapter of the Air Pollution Control Association. Plant interests may be served best by an informal group, made up of personnel active in the pollution control within the plants of the area. More formal developments of area industrial pollution control organizations have been created.[5] Any one of these can prove to be an excellent forum for discussion of mutual problems and exchange of experiences.

Win the Confidence of Civic Leaders, Health Officers, and Other Agencies of the Public

It should be recognized that the local health officers, or members of the municipal governing body can be a plant's understanding friends. It is good practice to invite these people into the plant. In this way they meet the responsible members of management and see for themselves the magnitude of the operations and pollution problems. They can then speak with the authority of knowledge when dealing with their public. And it is well to remember that accidental discharges of dusts, gases, etc., can occur in the best regulated plant!

Develop Good Community Relations

The word "community" as used here means the relatively small group held together by common interests, as typified by the average town and its industries.

Each plant has the continuing problem of being a "good neighbor" in its own community. A brief description of a tried and proved method for establishing good community relations is available.[2] This is the chapter on Community Relations of the Air Pollution Abatement Manual of the Manufacturing Chemists' Association. Quoting from this Manual: "Methods of abatement are almost entirely engineering problems. The reason for abatement is almost entirely the community relations problems engendered by pollution. This is a job for individual companies, working at the local level."

A few guideposts may be listed.

1. Tell the Employees. This is the most important single group for at least two reasons: First, air pollution abatement *depends* upon the co-operation of the employees. Second, they can be the most effective agents for good community relations, by telling their friends and neighbors of the company's efforts.

2. Arrange Plant Visits. Conducted plant visits can be very effective. These can include employees' families, neighbors, and the opinion-forming leaders of the community such as clergymen, educators, local officials, and newspaper editors.

3. Keep Enforcement Agencies Informed. As one industrial engineer of a well-known air pollution control agency has stated: "All we ask of industry is honest effort and information about what it is doing. Among other ends it serves, this information is often used to defend industry against public accusations."

4. Handle Complaints Promptly. This should be self-evident, yet how many plants have *all* supervision alerted to investigate complaints promptly?

5. Establish Good Press Relations. The press is essentially fair-minded and the public is remarkably patient, if the facts are made available and the facts indicate actions in good faith.

Examples of actual plant problems and how they were handled may be helpful.

To avoid water pollution of the Kanawha River, chlorinated hydrocarbon wastes of the South Charleston Carbide Plant are burned in an open burner. This seemed a happy solution to a serious problem—until some new catalyst mixtures were burned during a two-day atmospheric inversion with nearly 100% humidity. To make a long and sad story short that unhappy coincidence caused damage to the finish of hundreds of automobiles. How this situation was handled is quite a story in itself. The important point to emphasize here is the way this expensive lesson has been used to prevent repetition.

Metal plates, painted with car lacquers and enamels are now placed around the plant. Plant watchmen and gate guards are instructed to note and promptly report to the supervisors on duty any unusual emissions. By this means and by the regular inspection of the paint samples, no recurrence of extensive auto finish damage has occurred.

A particle-fall survey is being conducted in the general area surrounding one of the company's plants. This is a co-operative project in which Carbide and a neighboring plant of another company share the work and the costs. When this was being planned, it was agreed that the State Health Department should be invited to participate in the technical discussions. Not only was the invitation accepted; the Director of the Health Department even offered the use of their mobile laboratory. The mobile laboratory has not been needed, but by bringing the technical staff of the Health Department in on this work as it was being started, the equipment, methods of analysis, interpretation of results, and all other technical matters have been agreed upon by the industrial teams and the responsible health agency of the state. The data developed by this survey are not intended for public release. It is to be made available to the Health Department if needed.

This particle-fall survey is an interesting example of one of industry's most difficult air pollution problems. It involves fly ash emission from pulverized coal-fired boilers. Many plants have community relations problems because even the most expensive combinations of mechanical and electrostatic precipitators cannot prevent some dust escape to the air. The operation and proper maintenance of this type of equipment typifies the importance of the human element in the control of industrial air pollution.

As a fitting conclusion to this brief summary of a plant's day-to-day air pollution control and the related community relations, the final paragraph of the magazine article already referred to is quoted:

(*Continued on page 120*)

FILTERS *and Filter* MEDIA *for the* CEMENT *Industry*

RICHARD F. O'MARA and **CARL R. FLODIN,** O'Mara and Flodin, Inc., Los Angeles, Calif.

Introduction

Fabric filters of various types have long been the most common method of removing dust for many cement mill operation. The main exception was the cleaning of waste kiln gases. However, recently filters have also come into use for the cleaning of waste kiln gases from both wet and dry process kilns.

Through the years a wide variety of designs have been developed. These are in a constant state of improvement, such as metal frames taking the place of wood frames. Recently many new filter media have become available through the constant development and improvement of synthetic materials.

In the ordinary cement plant, 20 to 30 percent of the total waste gas to the atmosphere passes through fabric filters. Filters are commonly used throughout crushing plants as well as for the ventilation of transfer points, conveyors, elevators, air slides, bins and bagging equipment (Table I).

Filter Designs

The oldest and most common design are stockings or tubes—either circular or oval type individual bags. The bag diameter to length ratio is usually kept within a range of 20 to 25. Bag diameters generally vary from about 4 1/2 in. to 12 in. (Fig.1*A*).

In operation, the oval type bags become cylindrical and when the air flow is stopped, they revert to the oval arrangement which tends to remove the dust.

Multiple-bag envelope type construction allows for approximately 10 percent more cloth area in a given cross-sectional area. These are envelopes that are sewed so that in operation they become a group of circular elements. There is a seam at the top and several individual round connections in the bottom for fastening to the tube sheet (Fig.1*B*).

In the leaf type construction the cloth covers a metal frame that may be as large as 4 x 6 in. This forms a panel which is fastened in either the horizontal or vertical plane in the filter. Dust is collected on the outside of the panels and removed by various means (Fig.1*C*).

Filter Media

Over the years the most common fabric employed as a filter medium has been cotton. Cotton bags have been used for cleaning vent air from such sources as silos and bins, vibrating screens, transfer points on conveyors and elevators, air slides and Fuller-Kenyon conveying systems, raw mills and finish mills. The factors that dictated the use of cotton were low cost and suitability for the service.

Wool was not generally used in the cement industry. It is more expensive than cotton and is not required as is the case in the nonferrous metallurgical industry because of its greater resistance to attack by sulfur compounds.

In recent years a number of synthetic fibers have become available. Some of these are Dacron, Dynel, Nylon, and Orlon. Rayon and Teflon are available as filter cloth. Teflon is currently too costly for this service. Rayon has not proved particularly satisfactory. The two of these materials that have had the greatest promise are Dacron and Orlon.[2,3]

Felted Orlon was found to be a suitable filter material for use with the Hersey type reverse-jet filter. For filter purposes this material is supported on an open-weave base fabric. Orlon fabric has been used because of its resistance to possible chemical attack and abrasion. The maximum continuous operating temperature should not exceed about 250°F.

Heat-set Dacron is a suitable material for filters up to a continuous operating temperature of 350°F. It is used as a monofilament woven fabric and has a very smooth surface.[4]

Nylon is used for complete bags up to temperatures in the range of approximately 200°F. It is not generally used for higher temperatures because of shrinkage.

Dacron and nylon are also used for cuffs on cotton bags, to resist abrasion, and increase the useful life. However some plants are trying cotton bags without cuffs.

Dynel is a rather high priced material with very good corrosion resistant characteristics and is used mostly for wet filtration in chemical plants. It is not generally used for dry dust filtration.

Table II gives comparative properties of Du Pont fibers.

The newest filter medium is heat treated, silicone covered glass cloth. It is supplied in woven fabrics. Its recommended maximum continuous operating temperature is in the range of 500° to 650°F.

Filter media are available in a wide variety of fibers, counts, weaves, and weights and are supplied to meet the specification of bag manufacturers. The selection of the desired combination of factors for use in various applications depends on experience and preference of the manufacturer or user.

The most commonly used weaves are chain, twill, and satin.

An important index to the filtering characteristics of filter media is its porosity or permeability. *Permeability* is defined as the cubic feet per minute of air passing 1 sq ft of filter medium at 1/2 in. w. g. draft loss at ambient temperature. It should be noted that this is determined with clean air and is not directly applicable to the filtering ratio in a dirty gas stream. As used in cement plant practice, permeability may vary from about 10 to 35 depending upon the type of weave and filament characteristics of the fabric. Different permeabilities are used for various applications. Cotton ordinarily has a permeability of about 15.

The following are approximate comparative costs of various filter media:

Cotton	1
Orlon	2.5
Nylon	2.5
Dacron	2.5
Glass	3.0

Methods of Dust Removal from Filters

As usual with most dust separating apparatus, the separation of the dust from the gas stream is only a part of the problem. Frequently the real prob-

* Presented at the Air Pollution Control Association, 51st Annual Meeting, Sheraton Hotel, Philadelphia, Pa., May 25–29, 1958.

lem is the removal of the dust from the separator. Automatic shakers that give either vertical or lateral motion to the bags are arranged in many ways and can be operated through pneumatic, mechanical, or electrical means.

Almost all types of filters are, or can be, arranged so that the gas flow can be shut off and some gas allowed to flow back through the bag to assist in cleaning. This reverse air can be provided by a high pressure jet with a moving ring such as the Hersey type construction, or it can be provided by a fan either inside or outside of the filter casing proper.

Some filters are provided with dual dampers so that when a compartment is shut off for cleaning it is opened to atmosphere and the fan pulls atmospheric air or warm clean air through for reversing flow. For continuous service, this requires multiple-compartment construction of the filter.

With glass cloth bags, the gas flow to individual compartments is cut off and reversed with a time cycle control. This allows the bags to deflate for removal of the collected dust. Depending upon the dust load the cleaning cycle can vary from 30 min to 2 hr, or more.

Raw Mill and Finish Mill Systems

In raw mills filters are used for ventilation of the mill circuit. Where air separators are equipped with furnaces to provide drying, the filters are used for cleaning of the moisture laden air from the air separator (Fig. 2).

Air separators on finish mills are oftimes arranged so that large volumes of ambient air are pulled through the separator to remove some of the heat generated in grinding. In such cases the filter is connected to the warm air discharge from the separator.[5,6]

Table I—Filter Applications

Application	Ventilation of Material Handling Systems	Raw Mills—Air Separator	Finish Mills—Air Separator	Coal Pulverizer Vents	Kilns Wet or Dry Process
°F.	Ambient	160 to 220	160 to 220	Ambient to 180	400 to 650
Grains/cu ft	5 to 10	75 to 250	75 to 250	5 to 75	2 to 12
Pressure Drop, in. w.g.	3	3 to 4	3 to 4	3	2 to 6
Filter media	Cotton Orlon Nylon	Cotton Orlon Dacron	Cotton Orlon Dacron	Orlon Wool	Glass
Dust removal					
Shake and/or reverse flow	X	X	X	X	—
Deflating bags	—	—	—	—	X
Compartmented and dampered continuous automatic	X	X	X	X	X

Coal Pulverizers

Cotton fabric filters have been used to some extent for the cleaning of coal pulverizer vent gases but these are subject to fire and explosion hazard. More recently experiments have been under way with the application of glass cloth filters for this service.

Waste Kiln Gas Cleaning

A large installation of wool cloth was made on a wet process kiln installation as far back as 1927. Gas temperatures from the kiln were reduced by passing through a waste heat boiler immediately after the kiln, followed by a heat exchanger of the plate type and entered the collector at about 220 to 240°F. This method did not meet with any widespread acceptance in the industry due to the large size and high first cost of the installations as well as high power and maintenance costs. Average bag life was around nine months.

With the development of synthetic fibers that will withstand higher temperatures, pilot work was done with various types including glass cloth.

The advent of glass cloth appeared to have real promise for this application. However, although much money was spent and pilot plant installations made, varous shaking methods for removal of the dust without failure of the glass filter medium were unsuccessful and the idea lay dormant for from 10 to 15 years.

Three pilot plant glass cloth filter units on waste kiln gas were observed

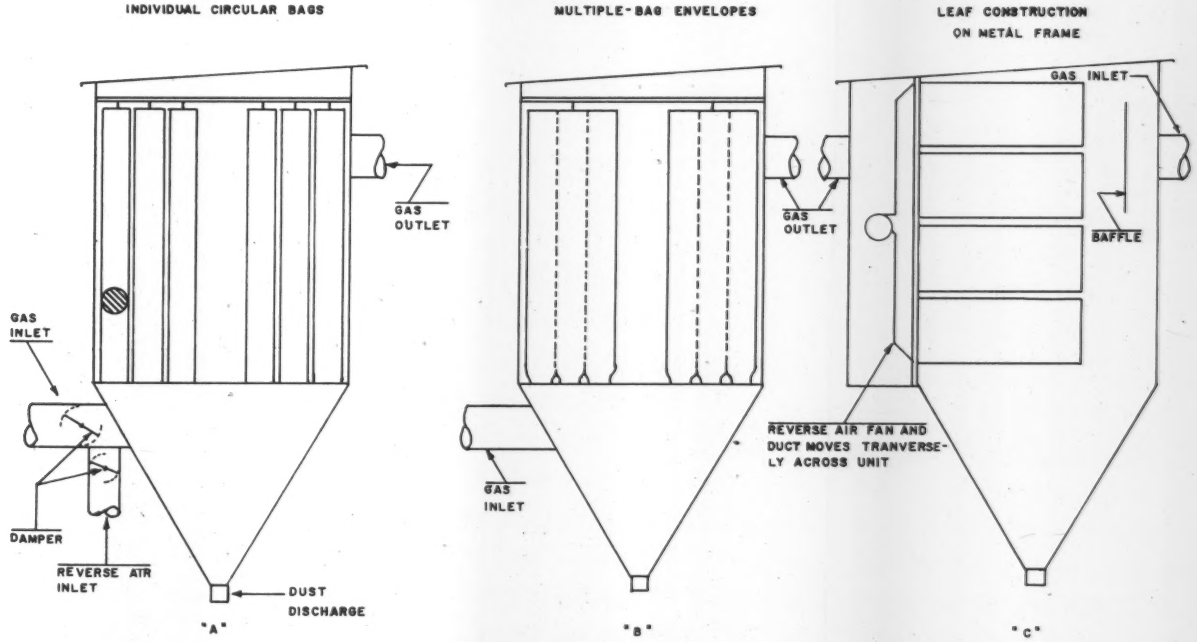
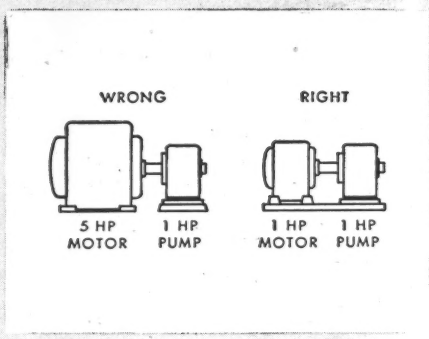


Fig. 1. Types of filters.

Tips on evaluating Electrical

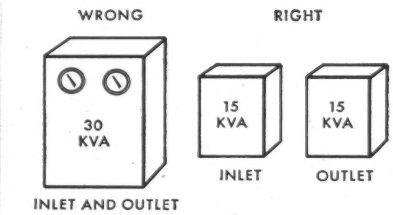
Matched Electrical Sets

You wouldn't use a 5 h.p. motor to run a pump that required only one h.p. Similarly, electrical sets should be *matched* to the requirements of the specific job. Electrical sets should be sized according to gas conditions, dust conditions, and other operating characteristics, and in accord with manufacturers' past experience on similar installations. *Don't be misled by high KVA ratings on the electrical sets.* The precipitator will only absorb a certain amount of power and the sets should be sized accordingly. A large excess of installed power, which will never be used, means inefficient use of the equipment.



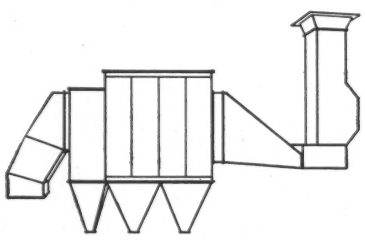
Varied Electrical Conditions

Electrical conditions in a precipitator can vary widely at different parts of the precipitator. For instance, a high voltage, low current condition usually prevails at the inlet where the dust load is high, as compared to a lower voltage higher current condition at the outlet. Consequently, it is good design (and a necessity for high efficiency) to furnish several electrical sections in series, with energization from separate electrical sets so that each section can be adjusted to best suit the conditions.



Gas Distribution

Remember that gas distribution, gas baffling, and provision against hopper sweeping all have a large influence on collection efficiency. The gas flow system should be analyzed as closely as possible, both in the precipitator and in the associated ductwork. If in doubt, have a three-dimensional gas flow study made. Two-dimensional gas flow studies *are not as accurate* and may lead to erroneous conclusions.

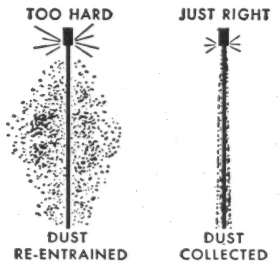


RESEARCH

RESEARCH-COTTRELL, INC. Main Office and Plant: Bound Brook, New Jersey

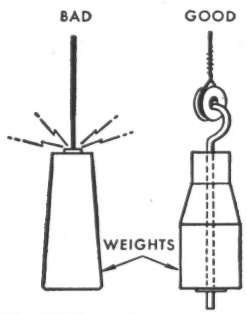
Precipitators

Some helpful hints to aid in selecting a properly designed unit



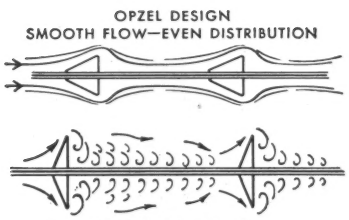
Rapping Intensity

Rappers should have easy means to vary the intensity of the blow to suit variations in operating conditions. A pre-set intensity setting cannot possibly give proper rapping over the normal range of operation. If too soft, build-up will occur which will disturb electrical conditions. If too hard, there will be reentrainment. Means of intensity adjustment are necessary to avoid drop-off of precipitator efficiency as conditions change.



Corona Discharge

It is a relatively easy matter to obtain a corona discharge in an electrostatic precipitator. Many types of discharge electrodes have been used over the past forty years, including ribbons, squares, twisted squares, star shaped sections, coiled wires, wires with prongs and projections, most of which give entirely adequate corona conditions. Final choice then gets down to mechanical factors such as strength of wire, method of support to avoid stress points, and ease of handling. There are many claims made for various types of wires but after investigating and testing hundreds of different kinds, we find a straight round wire about .1″ diameter to be best.



Baffle Design

Careful attention to the design of baffles on the collecting plates is most important. Small amounts of reentrainment mean tremendous differences in over-all collection efficiencies. It is seen that the "quality" of the collecting surface is far more important than quantity — quantity (sq. ft. of surface or treatment time) in itself is not a criterion of performance.

-COTTRELL

Representatives in all major cities of U.S. and Canada

in Germany. However, at the time of the inspection none were in operation. One used a rotary arm blow-back between glass covered panels while the other two used a reverse flow and moderate rapping on glass covered panels.

Two installations of this German development were made in this country. So far as is known, neither one is currently in operation.

New properties have now been provided for glass cloth by first passing it through a flame to remove the sizing or starches needed in the manufacture of the fiber. It is subsequently passed through an aqueous emulsion of silicone and then heat set at 500 to 600°F. This gives a very smooth finish. It is water repellant and has a very soft, flexible texture. It makes an excellent filtering surface since dust dislodges from it easily. Very few materials will stick to this silicone treated surface. It is even difficult to attach Scotch tape. Its application for the cleaning of cement kiln gases passed through several stages.

One of the large cement companies installed a suspension type heat exchanger on the feed end of kilns in one of their plants. The waste gas, after passing through mechanical collectors, went through a tubular type heat exchanger to reduce the temperature and was then vented to an orlon bag filter.

No satisfactory means to keep the heat exchanger surfaces clean was developed and the temperature without the heat exchanger was too high for orlon. About this time, this same company had a pilot glass cloth unit in another plant taking gases from a wet process kiln. This consisted of four bags, $11^1/_2$ in. diam x 15 ft long, and was arranged for mild shaking. Heavy shaking of silicone-treated glass cloth reduces the bag life.

The pilot plant unit had been operating for sometime when it was discovered that the shaking mechanism had not been operating but the unit was functioning satisfactorily. It was arranged to operate under pressure with the fan shut down for less than a minute out of each hour's operation by time cycle control. This allowed the bags to collapse gently and the dust to fall into the hopper. As a result of this discovery, glass bags were installed on the preheat kilns to replace the orlon bags.

In the meantime this cement company has continued to pioneer the development. They have designed and installed a full-size glass cloth bag filter taking all the gases from a 2500 bl/day wet process kiln. The gas volume is about 100,000 cu ft/min at 550°F. This installation has been in operation since October, 1957, and is still operating.

Table II—Summary of Properties of Du Pont Fibers

(Arranged in order of performance, courtesy of E. I. du Pont de Nemours & Co. Inc.)

Resistance to Dry Heat	Resistance to Acids	Resistance to Alkalies	Resistance to Oxidizing and Reducing Agents	Resistance to Moist Heat	Resistance to Abrasion (Wet and Dry)	Tensile Strength
Teflon[a]	Teflon	Teflon	Teflon	Teflon	Nylon	Nylon
Dacron[b]	Orlon	Nylon	Dacron	Orlon	Dacron	Dacron
Orlon[c]	Dacron	Dacron	Orlon	Nylon	Orlon	Orlon
Nylon	Nylon	Orlon	Nylon	Dacron	Teflon	Teflon

[a] Du Pont's registered trademark for its tetrafluoroethylene fiber.
[b] Du Pont's registered trademark for its polyester fiber.
[c] Du Pont's registered trademark for its acrylic fiber.

The installation consists of 12 compartments and operates under pressure. The gas flow to each compartment is cut off for approximately one minute at periodic intervals and cleaning is effected by deflating or flexing of the bags. Since a low sulfur raw material and natural gas as fuel is being used, the installation is allowed to vent directly to the atmosphere without a stack. It is arranged so that cooling air is drawn up around the bags by stack affect and the cloth temperatures never reach the incoming gas temperatures. The pressure drop is 2.5 to 3.0 in. of water. (Fig. 3 is a typical diagram.)

It is possible to walk into the cloth filter enclosure and around the various compartments with no throat or eye irritation. There is no visual discharge.

At an eastern cement plant two pilot units have been in operation for several months. One of these has four bags, $11^1/_2$ in. diam x 15 ft long. The other has 48 bags, $4^1/_2$ in. diam x 6 ft long, using a compressed air shock wave for dust removal.

Another cement plant has had a four

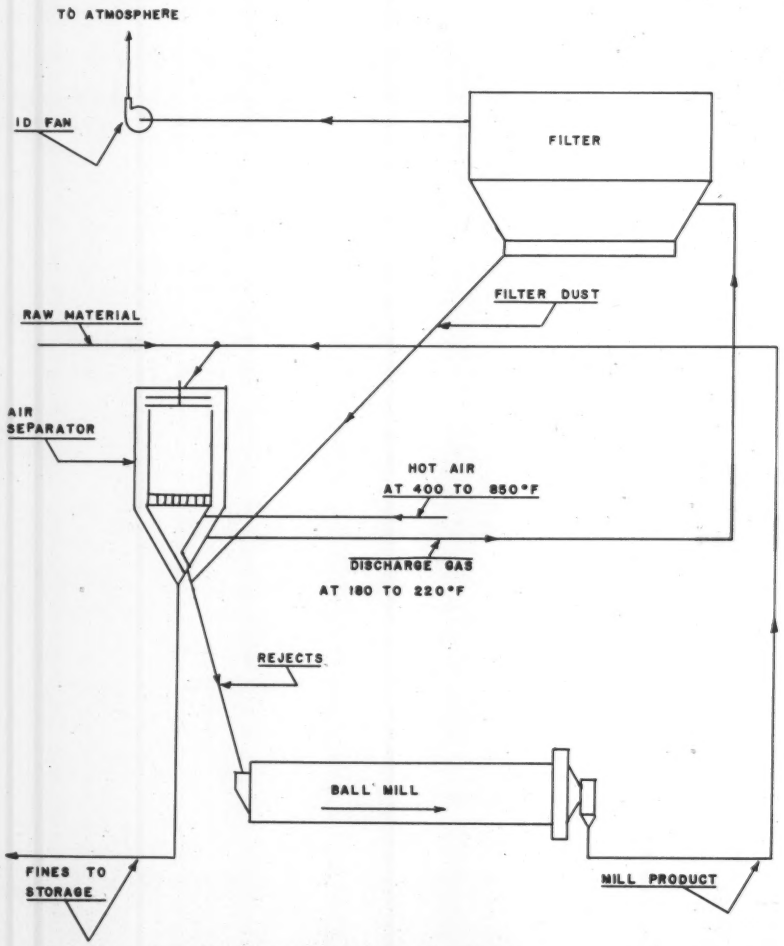


Fig. 2. Raw mill drying, grinding and separating circuit diagram.

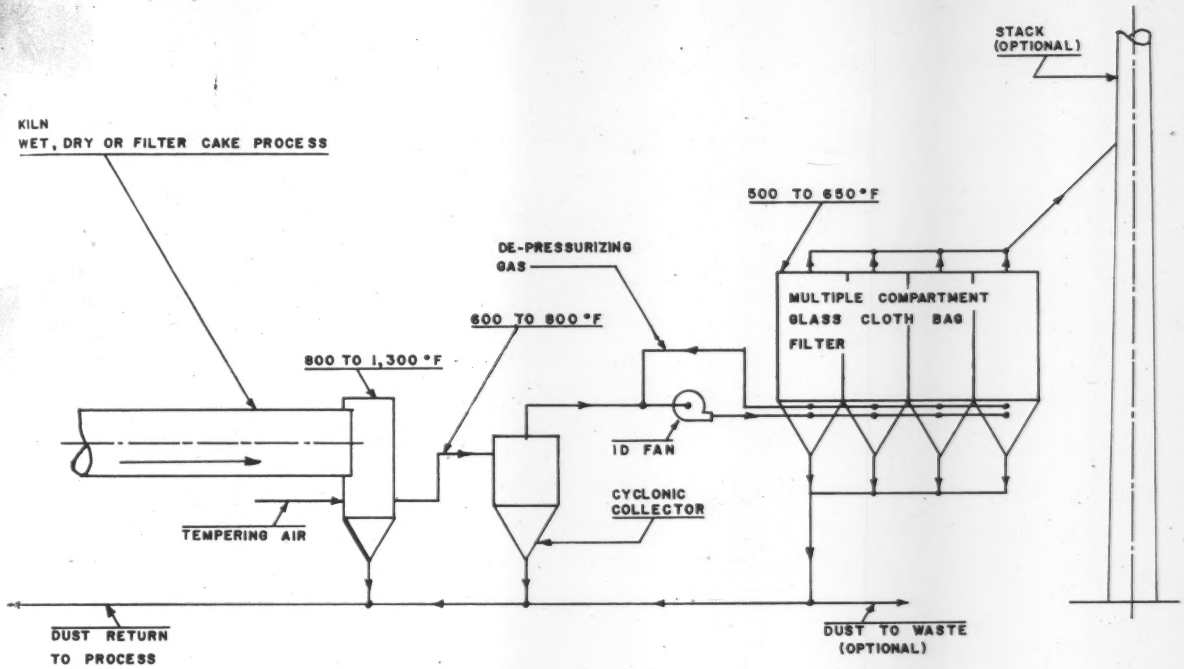


Fig. 3. Kiln gas cleaning.

bag pilot unit in operation for 10 months, and a 6000 cu ft/min test installation in operation since August, 1957. The pressure drop on gases as they come directly from the kiln is lower than it is after they have passed through mechanical collectors.

Other pilot installations are in process as well as at least two proposed full-size units to treat 200,000 cu ft./min each.

During the early experimental work it was thought that the alkalies in cement kiln gases would not be compatible with glass cloth fibers. However, in one plant relatively high alkali dust has now been collected since May, 1957, and the glass cloth has neither blinded nor has it given any indication of deterioration.

The dust recovered in glass cloth filters following mechanical collectors in two separate plants has a particle size range of 65 to 70 percent $-10\ \mu$.

In general the cloth to gas ratios for these applications are in the range of from 1:2 to 1:3.5. Pressure drops are in the range of 2 to 3.5 in. w.g. with exceptional cases as high as 5 to 6 in. w.g.

Glass cloth filters show considerable promise for the treatment of waste gases from both dry and wet process cement kilns. However, some time is required before sufficient operating experience on various types of plants will be available to fully evaluate economic factors such as power requirements and maintenance, particularly bag life.

Dryer Gas Cleaning

One large cement company has an installation on a limestone and clay dryer. They originally had orlon which lasted about two months. Glass has been in service since the middle of 1957 and still appears to be in good condition.

Preventive Maintenance

One of the most important considerations for filters in the cement industry is a program of preventive maintenance.

Shaking type filters should be checked at regular intervals to be sure that all of the shakers are functioning properly. Since none of the filters operate at 100 percent efficiency, there is always some small amount of dust that passes through, particularly during shaking. It is desirable that this dust be vacuumed out and the tube sheets kept clean. If dust is allowed to accumulate to any depth in the filter it impairs the operation and shortens the life of the filter cloth.

Patching materials are available for all types of bags.

It is ordinarily recommended that when a unit is taken out of service for maintenance, all of the bags in the unit be removed and replaced with a new set of bags or with a set that has been carefully repaired. This procedure has proved to be more economical than replacing individual bags.

REFERENCES

1. R. F. O'Mara and C. R. Flodin, "Engineering Design Factors in Dust and Fume Recovery Systems," Paper presented at APCA Semi-Annual Technical Conference in San Francisco, Calif. (Nov. 19, 1957).
2. E. I. du Pont de Nemours & Co. "Comparative Chemical Resistance of Fibers," Technical Service Section of Textile Fibers Department, Bulletin X-48 (March, 1956).
3. E. I. du Pont de Nemours & Co. "Comparative Heat Resistance of Fibers," Technical Service Section of Textile Fibers Department, Bulletin X-56 (September, 1956).
4. E. I. du Pont de Nemours & Co. "Filter Fabrics of Dupont Fibers," Technical Service Section of Textile Fibers Department, Bulletin X-64 (January, 1957).
5. C. C. Van Zandt, "Features Incorporated in the Design of Lone Star's Two New Dry Process Plants," *Mining Engineering*, pp. 1244–50 (December, 1952).
6. H. B. Howe, "New 2000 HP Clinker Mills Installed in Montreal East Plant of Canada Cement Company," *Pit and Quarry*, **50**, 6, 84–136 (December, 1957).

Investigating INHALATION *Hazard* USING *Synthetic* RADIOACTIVE FALLOUT

WILLIAM B. LANE, Technical Developments Branch,
U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

Introduction

Assessing the inhalation hazard from radioactive fallout has added another significant problem to the already complicated phenomenon of air pollution. Inhalation hazard depends upon the nature and amount of radioactive fallout as well as the chemical and physical properties normally associated with air pollution problems. Since the mission of NRDL is to develop countermeasures for passive defense against nuclear weapons, one of our tasks is to assess and predict the inhalation hazard which would be associated with nuclear weapon debris or fallout. Usefulness of our findings is not limited to atomic detonations but applies to nuclear reactor mishaps such as the Chalk River incident, to radioactive waste disposal, and, to some extent, to everyday problems of air pollution.

Laboratory studies of the internal hazard from nuclear debris require a synthetic fallout to simulate the contaminating event. Although contaminating events differ widely, their fallout may be grouped in four categories:

1. *Ionic*—the liquid contaminant resulting from a nuclear detonation in deep water.
2. *Slurry*—the wet contaminant from a nuclear detonation in a shallow harbor.
3. *Sintered*—in which the dry contaminant from a nuclear detonation over a land area has been heated to varying temperatures below the fusion point.
4. *Fused*—in which the dry contaminant from a nuclear detonation over a land area has been subjected to the extreme temperature of the fireball and the radionuclides homogeneously fused into the particle.

Synthetic fallouts are formulated to simulate these four categories and are used to generate aerosols for animal inhalation experiments. The kinetics of uptake distribution and retention of the radionuclides by the animals exposed to these aerosols can then be determined in serially sacrificed specimens during the course of the experiment. The gamma radiation levels in their tissues provide a measure of the internal radiation hazard.

An experimental program has been undertaken at USNRDL in which engineers, chemists, and biologists design exposure chambers, formulate radioactive aerosols, and assess the biological hazard by sacrificing exposed animals and analyzing organs and tissues for internally deposited radionuclides. This paper describes certain chemical and physical aspects of this program.

Background

Inhalation of an ionic aerosol was studied in an early experiment the results of which were presented to the Air Pollution Symposium in Atlantic City last year.[1] In this study a liquid aerosol was aspirated from a sea water solution containing multicurie amounts of fission products from neutron irradiated uranium. A second experiment[2] simulated the fallout from a nuclear detonation in a shallow harbor. The aerosol consisted of a wet particulate generated from a slurry of clay particles and fission products. A third experiment studied the syntheic fallout which simulated a nuclear detonation over a land area.[3] This was a dry aerosol in which the fission products were adsorbed to clay particles.

These past experiments indicated certain necessary modifications which have been incorporated in the experimental techniques to be described. Multicurie levels of fission products necessitated remote operations through protective shielding walls,[4] and radiation tolerance of the investigators limited the number of experiments. Problems inherent in measuring the gamma radiation from fission product were complicated by fractionation in the body processes. Furthermore, particle size, as well as the chemical properties of the carrier produced such complex results that the desired biological fate of fallout could not be determined. Experiments characterizing the interactions of single radioisotopes in each of the four synthetic fallouts were devised to yield data that could be treated separately or combined to describe and predict the inhalation hazard from a given contaminating event.

Present Inhalation Apparatus

The inhalation apparatus shown in Figs. 1 and 2 is enclosed in a controlled atmosphere glove box without radiation shielding. No shielding is necessary since the aerosol is traced with millicuries of radionuclides. The apparatus consists of a Roller particle size analyzer to generate the aerosol, a chamber in which the animals are exposed, and a millipore filter to collect the particulate in the exhaust. The flow system for the apparatus is shown in Fig. 3. The Roller analyzer successively removes and collects larger particle size fractions (2—60 μ diam range[5]) by air elutriation. A comprehensive study of the operating characteristics of the analyzer showed that for small particle sizes the rate of separation of material during the first 2 or 3 hr of the run remain constant.[6] Pressure-regulated and flow-controlled dried compressed air is introduced into a glass U-tube which serves as the sample reservoir. The sample is agitated in the air stream by a mechanical tapper. Only particles of the laden air stream having a certain minimum terminal velocity are carried through the separating chamber. Particles exceeding this minimum terminal velocity are returned to the inlet tube. Their return is

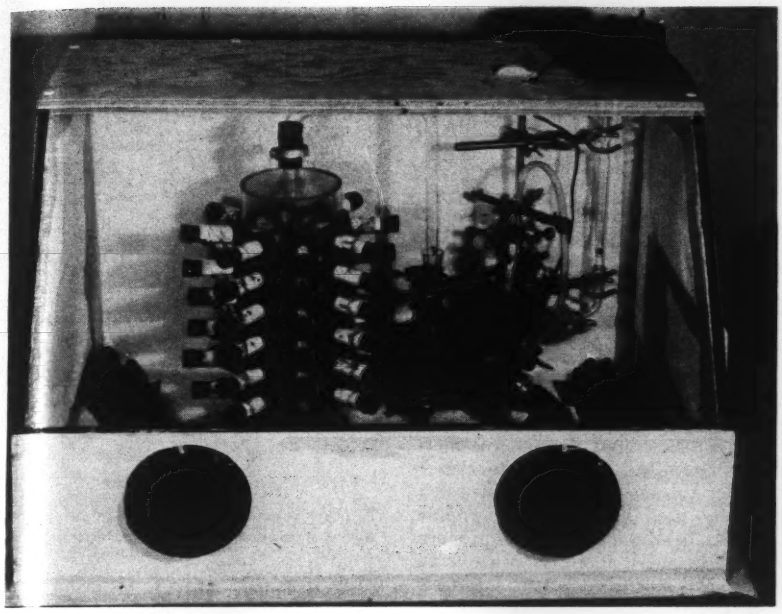


Fig. 1. Mouse inhalation chamber. (Method of exposing mice to radioactive aerosol is illustrated.)

facilitated by a second mechanical tapper which minimizes their tendency to cling to the walls of the separating chamber.

The animal chamber is connected directly to the outlet from the separating chamber and is designed to expose 48 mice simultaneously. The chamber is exhausted through a Venturi mixer through which outside room air is also drawn. The diluted exhaust is drawn through a millipore filter backed by a CWS filter. The laboratory vacuum system serves as the exhaust for the filtered air stream; air volumes are regulated through a flow meter to insure a slight negative pressure inside the boxes. A 3-hr exposure yields satisfactorily contaminated animals when the simulant is prepared from 0.5 g kaolin and traced with 500 microcuries of radionuclide.

Typical Experiment

Gamma emitting Sr^{85} was used to trace a dry aerosol of kaolin particles. The Sr^{85} was produced by bombarding a 2-g sample of rubidium chloride with deutrons in a cyclotron. Approximately 500 microcuries of Sr^{85} was separated carrier free as described by Overstreet.[7] The Sr^{85} was slurried with 0.5 g kaolin, and the mixture dried overnight at 165°C in a vaccum oven. It was ground under a heat lamp in a mechanical mortar and pestle and charged into the U-tube of the Roller analyzer. One liter of air/min produced an aerosol in the animal chamber which was strongly visible in a Tyndall beam. After a 3-hr exposure the animals were removed and counted in a liquid scintillation counter.

The animals were sacrificed in groups of six starting $^1/_2$ hr after exposure, and at convenient intervals up to 28 days. The distribution of gamma activity of the Sr^{85} was determined for the respiratory tract and lungs, and for the liver, tibia, head and gastrointestinal tract. The skin was removed from the animals and autopsies were carefully made to avoid cross contamination. The gamma activity in tissues was measured with a sodium iodide well crystal scintillation counter.

Results and Discussion

The uptake, distribution, and retention of Sr^{85} in the exposed mice is plotted in Fig. 4. The biological significance of these data will be treated in a subsequent paper by the Bio-Med Division.

An optical microscopic examination of an aerosol sample from the exposure chamber showed that the maximum diameter of the particles was 5 μ. Sixty percent of the particles ranged from 1 to 3 μ in diam. Limitations of such microscopic determinations of particle size distribution are well known and a more suitable method for this analysis is being developed.[8] A 100-mg sample is blown through a deagglomerator into a vertical tube. The rate of settling in the tube depends upon terminal velocity which is determined by the size of the individual particles. Arrival of individual particles on a film at the bottom of the tube is detected by beta backscattering and the measured backscattered radiation can be related to particle size distribution. This method is applicable to particles in the 1–100 μ range which obey Strokes' law. Submicron particles are studied by counting them as condensation nuclei.[9] A sample of aerosol is saturated with water vapor and expanded adiabatically. The expansion cools the air and produces an unstable condition of supersaturation which causes condensation nuclei to form a fog. The minimum size nuclei on which water

Fig. 2. Inhalation apparatus.

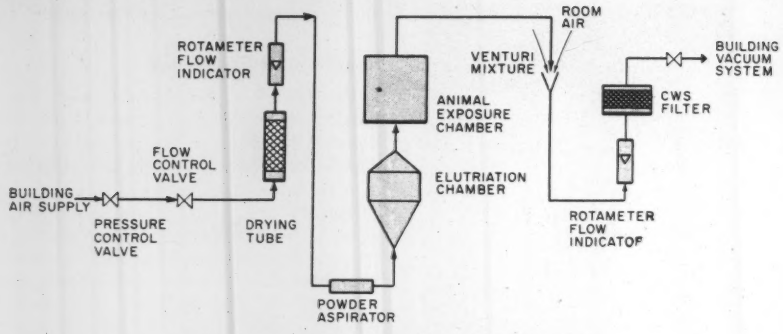


Fig. 3. Flow system for animal inhalation apparatus.

will condense may be controlled by varying the pressure during the adiabatic expansion. The attenuation of a light beam by the fog is measured with a light meter which is calibrated for a particle diameter range of 0.002–0.2 μ.

The present inhalation apparatus permits adequate control of the generated aerosols and the improved methods for particle size distribution analysis allows this parameter to be reported in meaningful terms. However, the true role of particle size in inhalation has not yet been determined since the synthetic fallout has been either ionic, slurry, or sintered, and the radiotracers have all been soluble to a degree in body fluids. Thus the radionuclide may have desorbed from the particle and been taken up by the body while the particle itself was not metabolized at all. The effect of solubility can be demonstrated by a comparison of an ionic simulant and a sintered simulant both traced with strontium. Three times as much strontium appears in the skeleton during the 28-day experimental period after exposure to a liquid aerosol as was observed following inhalation of the dry particle.

A fused simulant is required to satisfy the fourth category of fallout and also to make possible an evaluation of the effect of particle size in inhalation. A fused particle tagged with a radionuclide that is insoluble in the body fluids can be traced through the metabolic processes and its fate determined. A commercially available torch normally used in metal and ceramic spraying has been adapted to produce such radiotagged fused particles in an experiment now under way. A particle size distribution of clay particles has been developed which will flow through the constant feed mechanism into the combustion zone and give an adequate yield of subseive fused particles. Large volumes of dilution air for cooling the combustion gases are contained in a chamber to prevent escape of the radioactive aerosol. The micron size particles are collected from the fast moving air stream by electrostatic precipitation. Gram quantities of radiotagged fused particles will soon be produced.

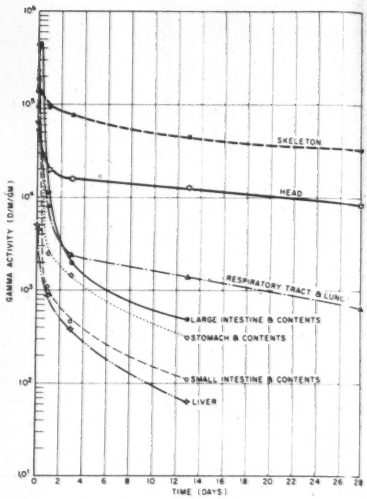


Fig. 4. Strontium per unit weight of organ following exposure to a dry particle aerosol.

REFERENCES

1. S. H. Cohn and W. B. Lane, "Air-Borne Simulants of Fallout from Nuclear Detonations: Preparation and Biological Applications," presented to Air Pollution Symposium in Atlantic City (1956).
2. S. H. Cohn, W. B. Lane, et al., "Inhalation and Retention of Simulated Radioactive Fallout by Mice: I. Study of a Simulant of Fallout from Nuclear Detonation Under Sea Water," *Arch. Indust. Health*, **14**, 333 (1956).
3. S. H. Cohn, W. B. Lane, J. K. Gong, R. K. Fuller, and W. L. Milne, "Radiotoxicity Resulting from Exposure to Fallout Simulant. II. The Metabolism of an Inhaled and Ingested Simultant of Fallout Produced by a Land-Based Nuclear Detonation," USNRDL TR-118 (1957).
4. J. C. Sherwin, W. B. Lane, et al., "An Apparatus for Exposing Mice to Radioactive Aerosols," USNRDL TR-78 (1956).
5. P. S. Roller, "Metal Powder Size Distribution with the Roller Analyzer," Special Technical Publication 140, ASTM, 54-65 (1952).
6. A. E. Reif and M. E. Giblin, "Aerosol Production and Size Analysis with the Roller Separator," *Arch. Ind. Health*, **14**, 442–449 (1957).
7. Coryell and Ingerman, *Radiochemical Studies: The Fission Products*, Book 3, page 1489.
8. L. W. Weisbecker, "A Terminal Velocity Particle Size Analyzer Utilizing a Beta Backscatter Mass Detector," presented at the Air Pollution Symposium in New York (1957).
9. P. J. Nolan and L. W. Pollak, "The Calibration of a Photoelectric Nucleus Counter," Proceedings of the Royal Irish Academy VLI, Section A, No. 2, Hodges, Figgis, and Co., Dublin (1946).

Plants POLLUTE *Air*

CDR. SIDNEY GOREN (MSC) USN

The literature makes frequent reference to a variety of adverse effects of air pollution on plant life.[1-3] This paper described a reverse situation which occurred following a record-breaking rainstorm on the Island of Oahu, T. H., where vegetation and inadequate drainage in an extinct volcano crater combined to create a prolonged air pollution problem.

This incident had its origin on Mar. 5 and 6, 1958, following a storm that released an average of 17.5 in. of rain on this small island in a 24-hr period. The area subsequently most affected is known as Makalapa. It houses senior Naval and Marine Corps officers and is located in the Pearl Harbor vicinity on the rim of the Makalapa Crater (Fig. 1). While the air pollution affected residents in this area by virtue of its proximity to the crater, it was, on occasion, carried for great distances by an unfavorable wind. Complaints were received from as far away as the Honolulu International Airport.*

"The statements made and opinions expressed herein are those of the author and not necessarily those of the Navy Department."

This incident occurred while author was on duty at the U. S. Naval Preventive Medicine Unit No. 6, Pearl Harbor, State of Hawaii. He is currently stationed at U. S. Naval Air Missile Test Center, Point Mugu, Calif.

Onset (History)

No disagreeable odor was noticeable until the fifth day following the storm (March 10) when a barely perceptible foul smell began to arise intermittently in the Makalapa Area. Those who first noted this foul odor indoors, immediately went out to see if it were present outside and those who were outside were surprised to find the odor when they went indoors. From this insidious onset, the condition became increasingly vile and lasted for longer periods. Several days were needed, however, for the residents to realize that the malodorous condition was more than just a passing unpleasantness. Thereafter, many residents of the Makalapa area as well as others outside of this area began to complain to the Territorial Health Department, Police Department Navy Medical Department, and others. Some living in Makalapa were stimulated by the odor to the point of nausea on frequent occasions during this period and the thought of abandoning their homes, at least until the condition passed, was entertained by some. There were times when the foulness would creep into the houses at night especially if windows were left open, and would be sufficient to rouse one from a deep sleep, almost to nausea. One means of bearing up was to close all windows and doors when a favorable breeze cleared the house of all foul odors. Liberal use of air deodorizers within the homes was of limited help.

Numerous theories circulated regarding the origin of the condition. Their variety is an indication of the degree of disturbance among the populace caused by the polluted air. One theory was, it was emanating from a small dairy farm located nearby; another, that large numbers of frogs had died in the crater as the rain rushed in from the surrounding areas, that pigs and cattle had drowned in the crater, that a slaughterhouse which no one could pinpoint was contributing, and also that a gas leak existed someplace. These are but a few that were in circulation when finally the Territorial Health Department as well as Army, Navy, and Air Force personnel entered the picture. Actually, all of the land from which the nauseating odor was emanating was ultimately determined to belong to the Navy, even though all service personnel as well as civil population was affected. The responsibility for handling the problem settled in the hands of the Navy Public Works Center with advice from the Navy Preventive Medicine Unit No. 6.

The Problem

Prior to 1938, the Makalapa Crater existed as a lake. In that year a considerable portion of Pearl Harbor near Pearl City, approximating 1000 ft by 10,000 ft was dredged and the silt hydraulically pumped into this crater. Eventually the floor was raised some 40 ft to its present level. This deposition of fine silt accounts for the present poor natural drainage and the high saline content of the crater pit. A sample of crater water taken at the time of this incident showed approximately 1700 grains of salinity per gallon which is further testimony to the poor drainage and low degree of leaching over the past 20 years. Elevating the crater level in the manner described gave rise to a dust problem when the winds swept over this new shallow basin. In order to control this situation the crater was seeded and the vegetation that ultimately survived and abounded in this high salt environment was a succulent plant known locally as the Akulikuli grass (Fig. 2). The rains which flowed into this natural collecting basin on March 5, from the surrounding areas, filled it and because of the inadequate drainage, natural and engineered, (Fig. 3, diagram 1) remained as a lake to inundate and destroy an estimated 80 acres of extremely heavy Akulikuli growth (Fig. 4). Calculations from a survey of this area made on March 18 to 20, 1958, by the Navy Public Works Center Engineers showed at least 25,000,000 gal of water remaining. This stagnant water caused the plant life to decompose. The odor which arose as a result of this underwater decomposition persisted for a period of more than two weeks and was much akin to that produced by an over-

* Possibly due to other areas closer to the airport in which similar plant decomposition was taking place.

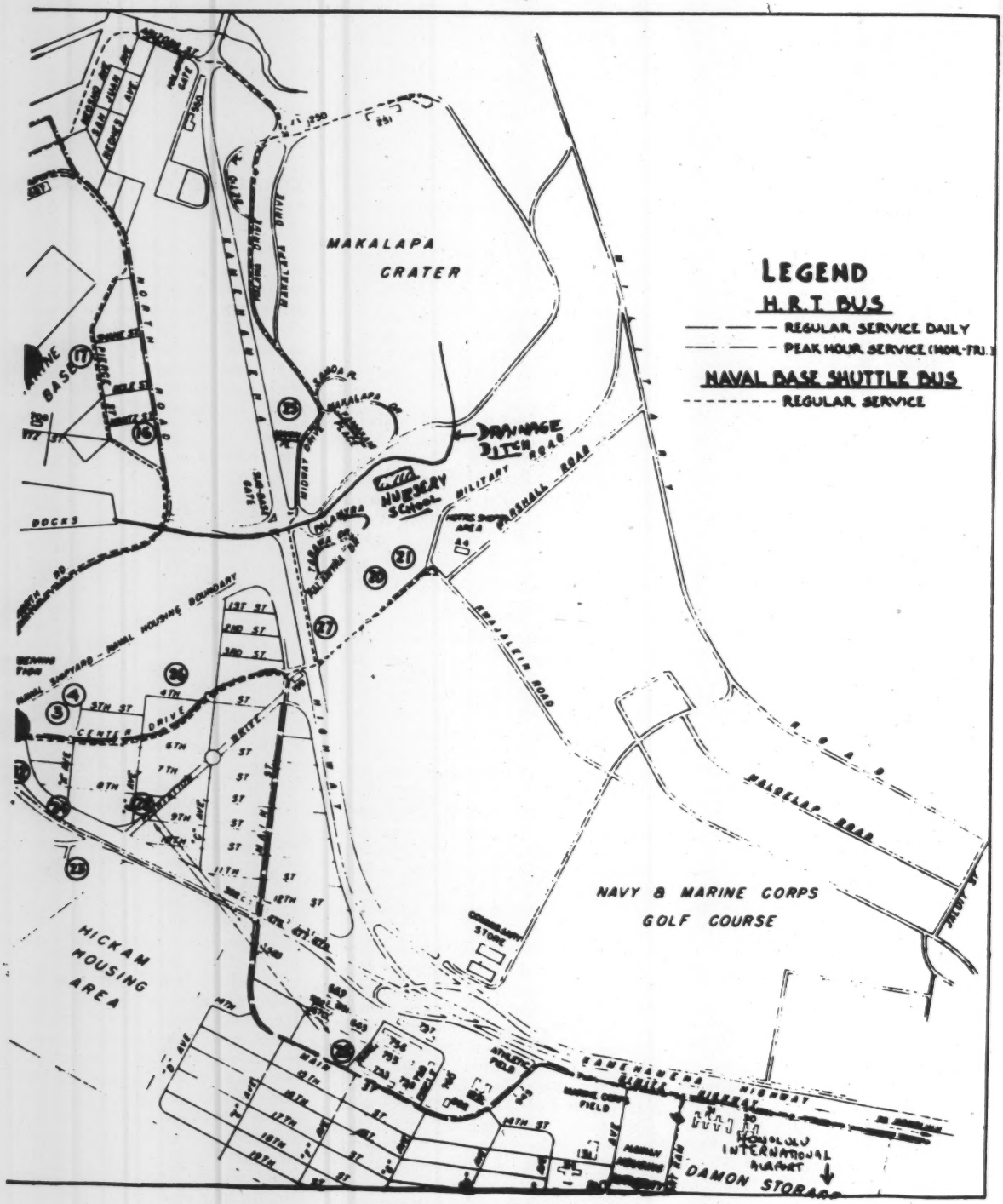


Fig. 1. Map of Naval base.

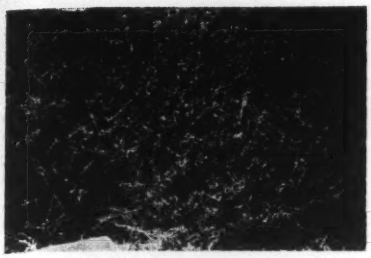


Fig. 2. Akulikuli grass, showing heavy growth.

ripe cabbage patch combined with a strong fecal stench.

Experimental

When the condition was recognized as more than just a transient one of a few days' duration, air and water samples were tested for ultimate breakdown products of protein decomposition but without success. It was assumed that the objectionable odors arose from anaerobic protein decomposition and contained putrescin, perhaps indoles and skatoles and other organic amines and mercaptans which our laboratory was unable to specifically isolate. Phosphotungstic acid caused a precipitate in a clear filtrate of a sample of the water and when treated with an alkali the clear filtrate gave the characteristic fishy smell of organic amines. Water samples were also sent to the University of Hawaii, Organic Chemistry Department, for assistance in determining the offending agents. Preliminary telephonic report from the Chemistry Department of the University confirmed the presence of mercaptans and amines likely to be formed during anaerobic decomposition. Specific solid derivatives of these substances were not identified. As regards to actual toxicity of the offending agent or agents which stimulated the vomiting center of some individuals, it is felt that no real basis existed for this in the concentrations present, but resulted purely from psychological stimulation. The odor was unquestionably a formidable affront to one's esthetic sense. As evidence in support of this theory, a nursery located adjacent to a runoff ditch of the crater water (Fig. 1) was visited and inquiry made regarding the effect on the children. While the odor had caused considerable concern among the teachers of the school, the children did not appear to be affected in any manner. In fact, some of them were not aware of any unpleasant "smell." The principal of the school was firm in her belief that no absenteeism from class has occurred because of it.

Three varieties of healthy plants were taken from the crater along with a sample of crater water for test purposes in the laboratory. These plants were placed in individual 2-l flasks, inoculated with a few milliliters of the

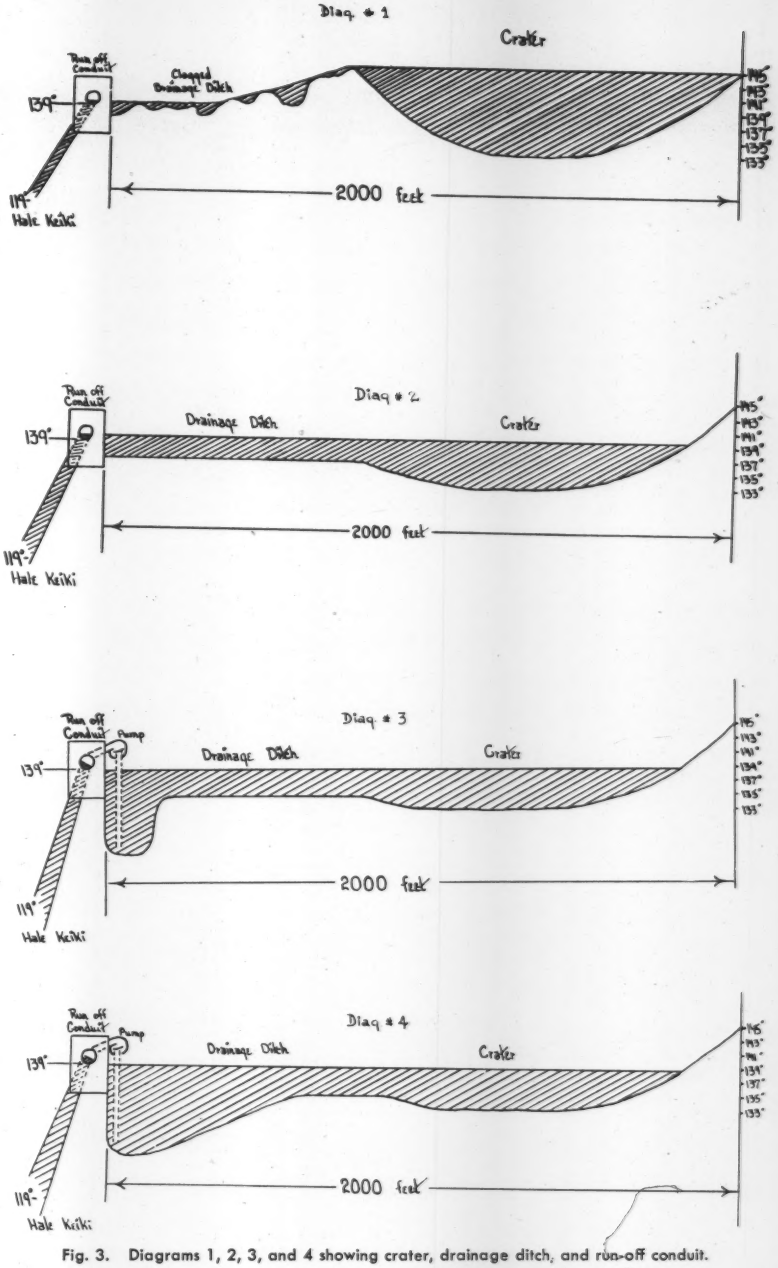


Fig. 3. Diagrams 1, 2, 3, and 4 showing crater, drainage ditch, and run-off conduit.

crater water and filled to just below the shoulder of the flask with tap water. The plants were completely submerged in all cases. The flasks were stoppered in order to collect any gases generated for test purposes. Each day the air in the neck of the flasks was sniff-tested and checked for hydrogen sulfide. After two or three days, foul odors were noticeable in each of the flasks. However, the one containing Akulikuli gave definitely more odor even though all were reminiscent of the foulness emanating from the crater. This established the cause of the air pollution as putrification of the plant life. It was not until the sixth day that traces of hydrogen sulfide began to appear and was detected by lead acetate papers suspended in the necks of these flasks. Thus, the cycle of the occurrence in the crater was successfully simulated in the laboratory.

Two weeks after the appearance of the fetid odor in the neighborhood air, hydrogen sulfide was qualitatively demonstrated in air and water by lead acetate papers. This odor was a welcome change from the foul putrid smell of the previous weeks and its appearance signaled the retrogression of the acutely offensive phase. Hydrogen

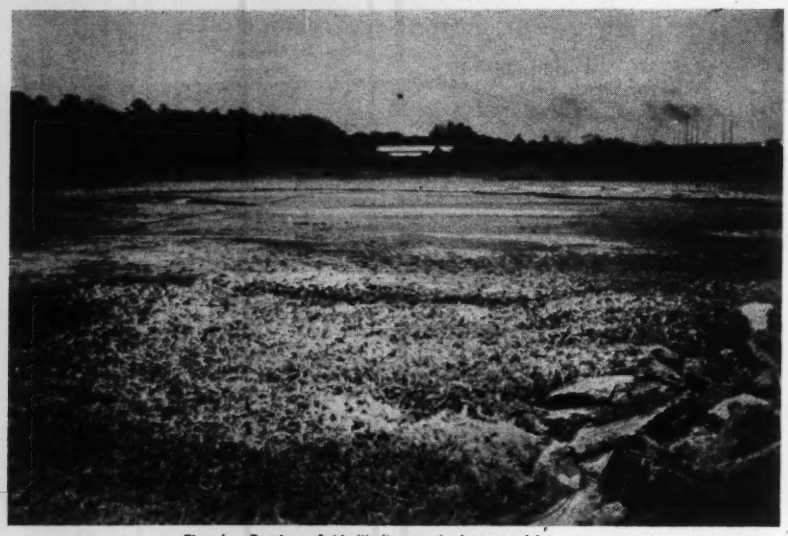


Fig. 4. Portion of Akulikuli growth destroyed in crater.

Fig. 5. Pumping crater run-off into culvert.

Fig. 6. Discoloration around screen frames and siding of quarters due to H_2S combining with lead pigment of paint.

Fig. 7. Discoloration around screen frames and siding of quarters due to H_2S combining with lead pigment of paint.

sulfide was never present in levels dangerous to health except at the drainage ditch where water was being pumped into a concrete culvert (Fig. 5). At this point quantitative grab samples of air using an MSA H_2S indicator and tubes showed as much as (20 ppm.)

The new odor brought complaints of rapid tarnishing of copper and silverware in the homes of Makalapa residents. House paint also became visibly affected in many of the homes (Figs. 6 and 7). Mostly those portions of the houses facing the crater were affected, causing screen and door frames and portions of the siding to turn dark, almost a purplish gray. This same effect was duplicated in the laboratory by exposing screen frames to hydrogen sulfide. The outside paint used on these homes was a standard navy oil based paint containing white lead. The reaction therefore was determined to be that of H_2S on lead, producing a lead sulfide.

The hydrogen sulfide phase of the pollution continued for a period of approximately 10 days in all. Several days following the disappearance of all noxious odors from the atmosphere the house paints returned to their normal appearance as a result of further oxidation of lead sulfide to lead sulfate.

Summary

An air pollution incident is recounted as a result of a freak, record-breaking rainstorm inundating a large area of a succulant plant growth which subsequently decomposed anaerobically. Drainage in the past was always adequate for the usual rainfalls and little attention had been given to upkeep of the engineered drainage system. This incident with its resultant air pollution problem emphatically demonstrates the need for an adequate drainage system

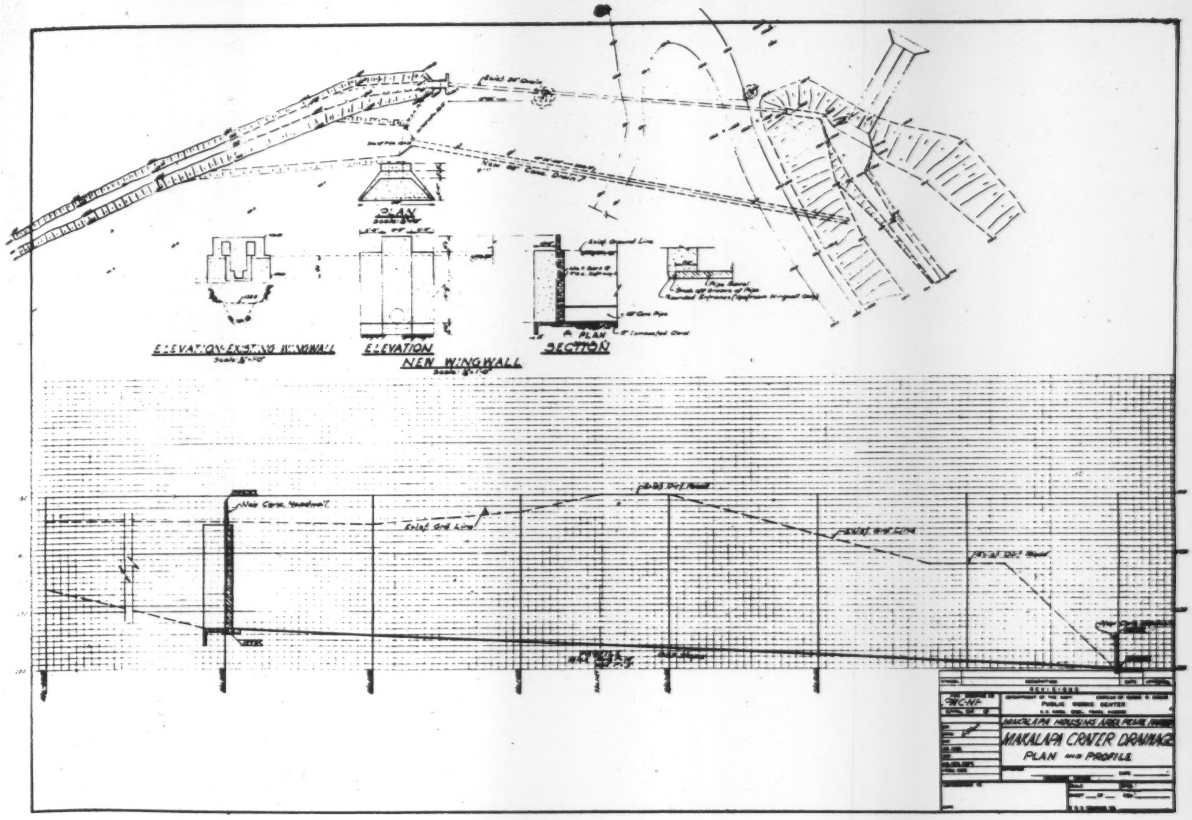


Fig. 8. Makalapa housing area at Pearl Harbor.

through engineering means and its proper maintenance where the natural drainage is inadequate.

Fig. 3, diagrams 1, 2, 3, 4, show schematically the sequence of events in correcting the condition through drainage of the crater.

Fig. 3, diagram 4, shows the present plan for improving drainage to avoid a recurrence.

REFERENCES

1. C. R. Metcalf, "Damage to Greenhouse Plants Caused by Town Fogs with Specific Reference to Sulphur Dioxide and Light," *Ann. Appl. Biol.*, **28**, 301–305 (1948).
2. P. W. Zimmerman, "Impurities in the Air and Their Influence on Plant Life," Proc. First National Air Pollution Symposium, Stanford Research Institute, Pasadena, Calif. (November, 1949).
3. M. B. Katz, et al., "Effect of SO_2 on Vegetation, National Research Council of Canada, Associate Committee on Trail Smelter Smoke," Report 815, 447 pp., Ottawa, Canada (1939).

LAUREN B. HITCHCOCK ASSOCIATES

Chemical Engineers

INDUSTRIAL AIR POLLUTION ABATEMENT

L. B. Hitchcock—Edwin Cox

J. H. Schaefer, Technical Advisor

60 East 42nd Street
New York 17, N. Y.
YUkon 6-4628

Continuous DETERMINATION *of* CARBON MONOXIDE *and* HYDROCARBONS *in Air by a Modified* INFRARED ANALYZER*

MORRIS B. JACOBS, Ph.D., P.E., Director of Laboratory
M. M. BRAVERMAN, Chief Chemist, and **SEYMOUR HOCHHEISER,** Chemist

The continuous analysis of micro quantities of gaseous air contaminants has long been the goal of workers in the field of air pollution control. The estimation of hydrocarbons and carbon monoxide in small amounts in the ambient air has been difficult but, with a suitable modification of the nondispersive type of infrared gas analyzer, continuous analysis in low concentrations has been achieved. The use of this instrument for the determination of carbon monoxide in New York City atmosphere was discussed by Jacobs.[1]

In 1892 Julius[2] showed the relation between infrared spectra and the structure of organic molecules; and the possibility of using the infrared spectra of a molecule for analytical purposes.

In 1905 Coblentz[3] not only gave a complete discussion of instruments, methods, and techniques, but also presented data for a very wide range of organic and inorganic compounds.

Infrared gas analyzers depend on the absorption of infrared radiation by compounds. This absorption is characteristic of the type and arrangement of the atoms composing the molecules. The wave length at which absorption occurs is determined by the mass of the atoms and the force of the bond holding them together. Dissimilar compounds absorb in widely different spectral regions but similar compounds absorb in adjacent spectral regions. For instance, methane, propane, and hexane absorb closely related wave lengths with slight absorption differences. On the other hand, water vapor, ammonia, sulfur dioxide, carbon monoxide, and methane differ greatly in their absorption patterns. Because of these differences, a small amount of one of these gases can be estimated in the presence of a much higher concentration of the others.

There are several types of infrared

* Contribution from the Bureau of Laboratory, Department of Air Pollution Control, City of New York.

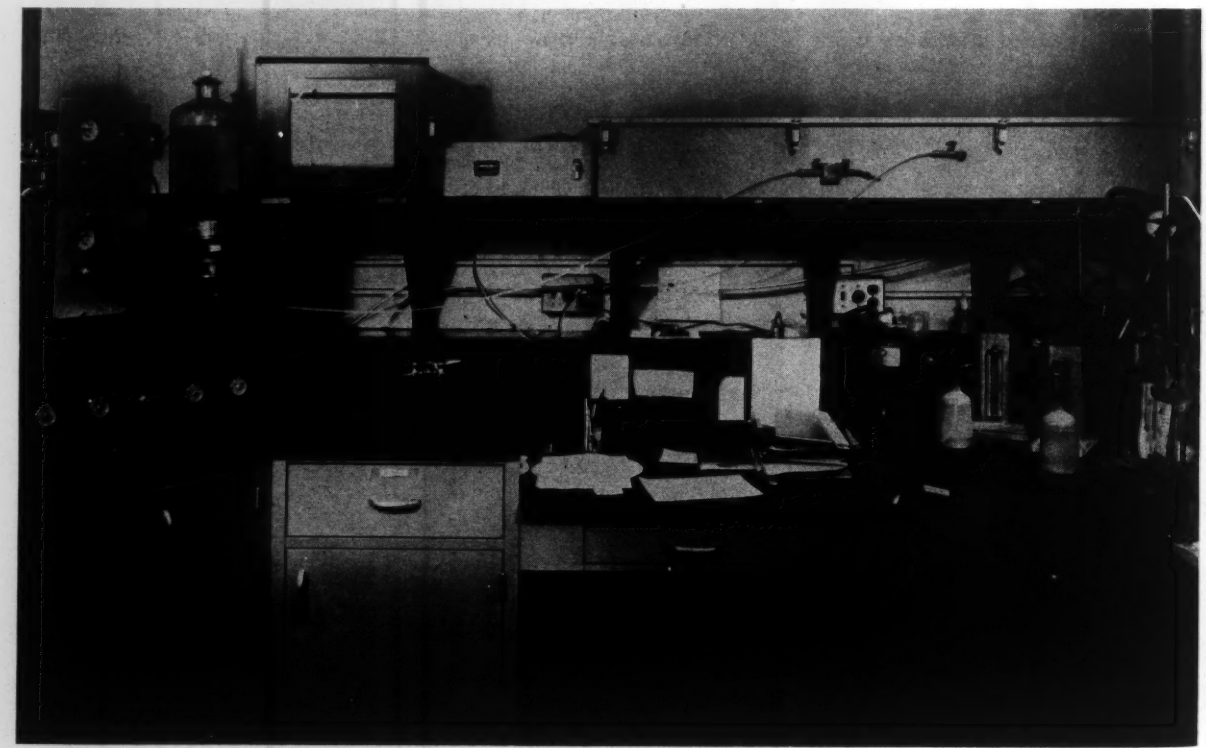


Fig. 1. In this section of the laboratory of New York City's Department of Air Pollution Control, two M-S-A LIRA infrared analyzers are used. One measures carbon monoxide content of the outside air; the other measures hydrocarbons. The special humidifier incorporated by the authors is mounted on the upper right corner of the common control panel seen on the left.

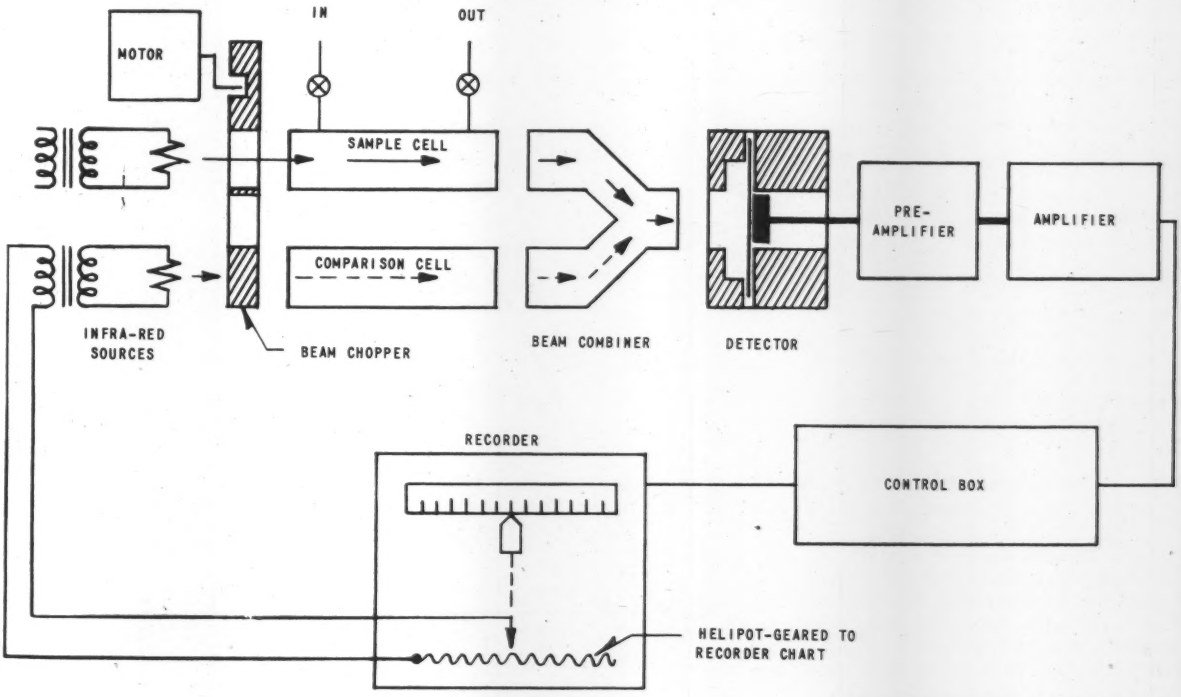
analyzers but the instrument described here is of the selective, nondispersion type.[4] (See Figs. 1 and 2.) Basically this consists of an infrared source, a sample and filter cell, and an infrared detector. This analyzer measures the absorption by the sample of radiation in those spectral regions which would normally reach a detector and cause an output signal. With suitable detectors and sensitizing methods, the analyzer can be made selective and very sensitive to minute concentrations of one compound.

Apparatus

Principle

The MSA Luft-type infrared gas analyzer[5] is a nondispersive, selective, infrared analyzer. Essentially the analyzer consists of an infrared source, a sample and comparison cell, a beam combiner and filter cell, a detector cell, an amplifier and a recorder as shown in Fig. 3. Two similar nichrome filaments are used as sources of infrared radiation. The beams from these filaments travel through parallel gold-plated, stainless-steel cells. One beam traverses the sample cell and the other the comparison cell. The emergent radiation is converged into a single detector cell by a beam combiner. As the gas in the detector absorbs radiation, its temperature and pressure increase. An expansion of the detector gas causes the membrane of a condenser in a microphone to move. This movement when converted electrically and amplified produces an output signal. Between the source and the cells a reciprocating metal slider (or beam chopper) alternately blocks the radiation from the sample cell and the comparison cell respectively. When the contaminant whose concentration is to be measured is not present in the gas stream of the sample cell an equal amount of radiation enters the detector from each cell. The amplifier is tuned so that only variations in light intensity occurring at the alternating frequency produce an output signal. Therefore, the beams are equal and output is zero.

Fig. 2. Dr. Morris B. Jacobs, director of laboratory for New York City's Department of Air Pollution Control, adjusts the level of water in a special humidifier incorporated in his laboratory's M-S-A LIRA infrared analyzers.



Mine Safety Appliances Co., Pittsburgh, Pa.

Fig. 3. Basic infrared analyzer system M-S-A LIRA.

When the gas to be analyzed contains the contaminant and is introduced into the sample cell, it absorbs infrared radiation and thus reduces the radiation reaching the detector from the sample beam. As a result the beams become unequal and the radiation entering the detector varies as the beams are alternated by the beam chopper. The detector gas expands and contracts in accordance with this variation or flicker. In this way the detector directly indicates the difference between the two beams. The expansion and contraction of the gas causes the microphone diaphragm or membrane to move in response to the variations. The membrane movement, in turn, varies the condenser capacity. This variation in capacity generates an electrical signal which is proportional to the difference between the two radiation beams. This electrical signal is amplified and causes an electronic recorder to drive up scale. The position of the recorder indicator is then a measure of the absorption of the sample and hence the concentration of the component being determined. Thus the recorder automatically and continuously provides a record of the contaminant in the sample mixture.

Selectivity

The instrument is selectively sensitized by means of the source window, the filter gas contained in the beam combiner, the detector window, and the detector gas. The instrument is specially sensitized for carbon monoxide by filling the detector with four percent carbon monoxide in argon and filling the filter cell with 50 percent carbon dioxide and 50 percent isobutane. The comparison cell is filled with a nonabsorbent gas, namely, dry nitrogen. Calcium fluoride windows are used in both the source and detector windows.

The instrument is selectively sensitized for hexane by filling the detector with two percent hexane in argon and the filter cell with 50 percent carbon dioxide plus 50 percent carbon monoxide. The source window is made of quartz and the detector window is made of calcium fluoride. In this instance also the comparison cell is filled with nitrogen gas.

Sensitivity

The sensitivity of the instrument can be increased by increasing the length of the sample and comparison cells. In air pollution work low concentrations of contaminants are encountered. For example, in an air sample the concentration of carbon monoxide is in the range of 0 to 50 ppm and that of hydrocarbons (as hexane) is in the range 0 to 10 ppm. The length of sample cell required for concentrations of this order or magnitude is 40 in. Over-all length of the instrument, plus the recorder, requires a space of $8^1/_2$ ft. The size of this instrument is therefore too great for portability.

The sensitivity can also be increased by increasing the pressure of the sample gas. This is accomplished by means of a compressor pump. A dust filter is attached to the gas inlet of the compressor to prevent passage of particulate matter into the analyzer. For the analysis of air samples containing the concentration of pollutants mentioned pressures of 15 to 150 lb are required.

The instrument sensitivity can also be varied electrically to a limited extent by adjustment of the span in the control box.

Modified Lira-type Infrared Analyzer

Water vapor has an absorption throughout the infrared region and is therefore an interference in the analysis of carbon monoxide and hydrocarbons. For example, nitrogen saturated with water at 70°F is equivalent to approximately 5 ppm CO or 5 ppm hydrocarbons. Mine Safety Appliances Company attempted to remove water vapor from the incoming air sample by leading the sample through two traps before it entered the analyzer. The first trap was filled with Drierite. This method of drying the air sample was found to be ineffective. An additional procedure attempted was to provide the intake pump with a valve which permitted the water condensed in the compressor to escape. This reduced the load on the Drierite.

Since neither of these approaches worked we decided to introduce a constant error by saturating the incoming air stream with water vapor. This was done by filling the two traps provided with the instrument half-full with water and maintaining the water level during the calibration and air sampling. Since the temperature of the instrument is thermostatically controlled, the concentration of water vapor is constant and can be eliminated as a variable by adjustment of the controls.

Calibration

Standard gas mixtures are used for the calibration of the analyzer. The concentration of the standard gas needed depends upon the analysis requirement. The standard mixtures found to be most suitable for the measurement of carbon monoxide and hydrocarbons as hexane in air are 10 and 30 ppm for carbon monoxide and 5 and 10 ppm for hexane. Prepurified nitrogen gas is used to set the base line or zero. The purity of nitrogen is extremely important as traces of impurities in the nitrogen may be greater than the concentration of the contaminant in the sample. For atmospheres subjected to ordinary city air the range requirements for carbon monoxide measurements is 0 to 20 ppm and for hydrocarbons 0 to 5 ppm.

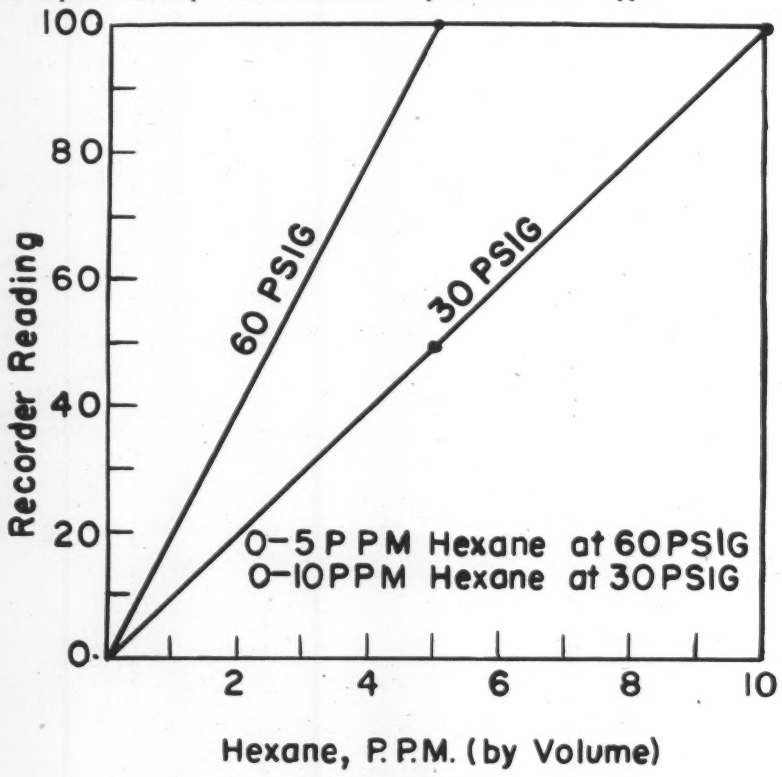


Fig. 4. Calibration curve.

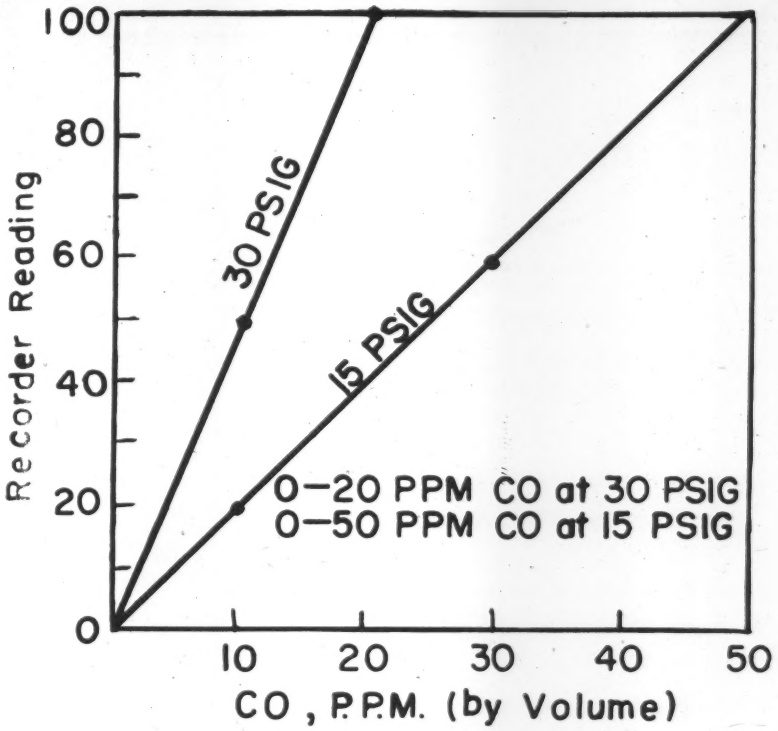


Fig. 5. Ppm by volume hexane.

Atmospheres in areas of heavy traffic conditions contain concentrations of the order of 0 to 50 ppm carbon monoxide and 0 to 10 ppm hexane and the instrument should be set for this range.

To calibrate the instrument it is necessary both to adjust the sampling pressure and to set the control span. This will yield the suitable instrument sensitivity.

Nitrogen gas is introduced into the analyzer to set the base-line or zero reading at the operating pressure which is controlled by means of a gas diaphragm regulator. The rate of gas flow through the analyzer is usually set at 2 to 5 cfh. The recorder indicator is adjusted to read zero at the trial operating pressure by means of the zero adjustment control located in the control box of the instrument. The appropriate standard gas is then introduced into the analyzer at the trial pressure and the span control is adjusted so that the recorder indicates the standard gas on the recorder scale.

If the desired span cannot be attained the pressure is changed and the zero reading obtained with nitrogen gas is again determined. The 10 ppm standard carbon monoxide mixture is set at 50 percent of the scale reading when the range requirement is 0 to 20 ppm and the 10 and 30 ppm standards are set at

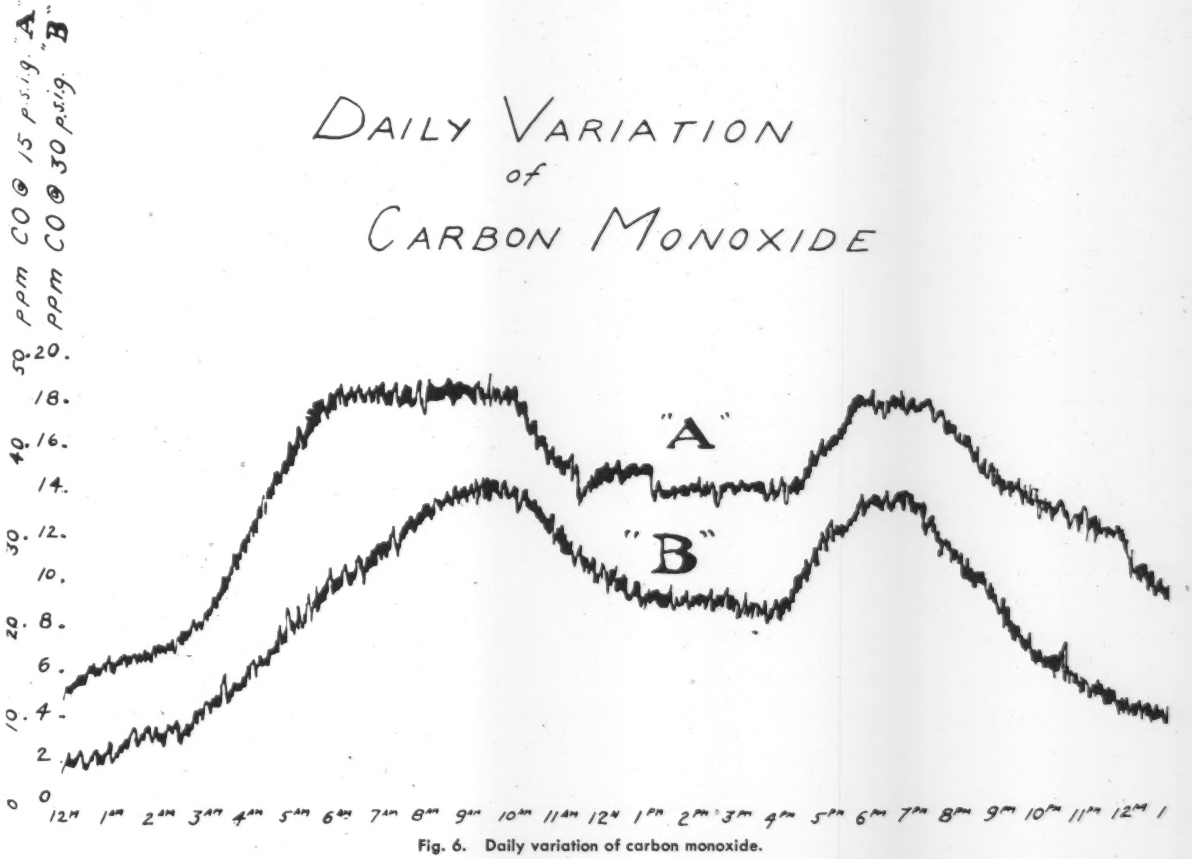

DAILY VARIATION
of
CARBON MONOXIDE
50 ppm CO @ 15 p.s.i.g. "A"
40 ppm CO @ 30 p.s.i.g. "B"
50. 20. 18.
40. 16. 14.
30. 12. 10.
20. 8. 6.
10. 4. 2.
0 0
"A"
"B"
12M 1AM 2AM 3AM 4AM 5AM 6AM 7AM 8AM 9AM 10AM 11AM 12N 1PM 2PM 3PM 4PM 5PM 6PM 7PM 8PM 9PM 10PM 11PM 12M 1

Fig. 6. Daily variation of carbon monoxide.

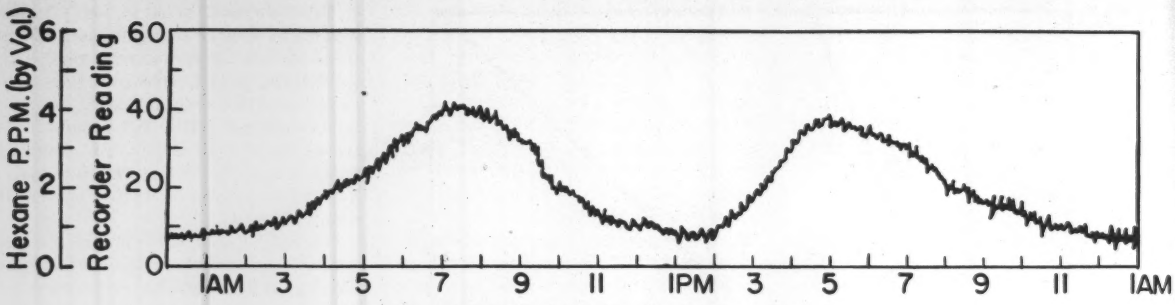


Fig. 7. Daily variance of hexane.

20 and 60 percent of scale in the range 0 to 50 ppm. The scale is linear in this range.

The 5-ppm hexane standard is used for calibrating the hydrocarbon analyzer for the range 0 to 5 ppm and both the 5- and 10-ppm hexane mixtures are used to calibrate the instrument to read 0 to 10 ppm (Figs. 4, 5.)

Procedure

After the instrument is calibrated the outside air sample is drawn continuously into the analyzer at the selected pressure by means of the compressor pump. Tygon or polyethylene tubing is used to carry the outside air into the compressor. A Bristol recorder equipped with a 30-day chart continuously and almost instantaneously records the concentration of the pollutant. Water is added or withdrawn from the traps daily in order to maintain a constant water level. The analyzer is calibrated three times a week.

Results

The daily variation of hexane and carbon monoxide during a typical day of high pollution is illustrated in Figs. 4 and 5. It can be seen from Fig. 6 that the concentrations of carbon monoxide at the two sampling sites varies in the same manner. The peaks in the curve at 6 to 10 A.M. and 5 to 8 P.M. correspond to and correlate with the traffic density normally occurring during these hours of the day. It is also noted that the concentrations represented by curve (*a*) are three to four times higher than curve (*b*). The variation of hexane at station (*b*) is 0 to 1 ppm. It can be seen from curve (*a*) in Fig. 7 the daily variation of hexane at that site shows a similar relationship for the concentration of hexane.

Discussion

The concentration of air pollutants represented by curve (*b*) is determined by analyzers located one flight above street level in an area of medium motor vehicle traffic. Air sampling at station (*a*) is conducted at street level at the Manhattan end of the Queensboro Bridge. A traffic light at the end of the bridge stops traffic periodically. The concentration of carbon monoxide and hydrocarbons emitted by automotive exhausts as determined by means of infrared analyzers at the two locations can therefore be compared. The major variables are traffic density and height above street level. The atmospheres at these sampling sites were selected for air monitoring since they are representative of air breathed by municipal dwellers. A continuous determination of the extent of air pollution with respect to carbon monoxide and hydrocarbons to which pedestrians and motorists are exposed at street level and the concentration of pollutants to which persons are exposed in dwellings above street level can be made with these instruments. It should be emphasized that although sensitivity is proportional to the pressure, the rate of sampling has no effect. This is true because the ratio of the infrared absorbing molecules to the nonabsorbing molecules is constant for the same concentration of contaminant irrespective of the rate of flow at constant pressure. This can be demonstrated by measurement of a standard gas mixture at varying rates of flow.

Acknowledgment

The authors wish to express their appreciation for the assistance given them by Victor Elliot of Mine Safety Appliances Company and to Theodore Aubertel, Department of Air Pollution Control, City of New York, for their assistance in this investigation.

Summary

By increase of length of the sample tube and by increase of the pressure of sampling of the Lira-type infrared analyzer, the sensitivity of this instrument was increased sufficiently so that it could be used for the direct measurement of carbon monoxide in the ranges of 0 to 20 ppm and 0 to 50 ppm and of hydrocarbons such as hexane in the ranges of 0 to 5 ppm and 0 to 10 ppm. The elimination of the interference of water vapor attributable to its absorption in the infrared by saturating the air stream with water vapor and adjusting the controls has made the instrument suitable for continuous determination of air contaminants in the ppm range.

REFERENCES

1. Morris B. Jacobs, "Variation of Carbon Monoxide Concentration in New York City Atmosphere," Am. Chem. Soc. New York Section Meeting-in-Miniature, New York (March, 1958).
2. W. F. Julius, *Verhandel Akad. Wetenschappen Amsterdam*, **1**, 1 (1892).
3. W. Coblentz, Carnegie Institution Bulletin 35 (Washington), 1905.
4. Mine Safety Appliances Company, *Instruction Manual for Lira Infra-Red Analyzer*, Pittsburgh (1958).
5. J. L. Waters and Nelson W. Hartz, Conference Instrument Soc. Amer., Houston (September, 1951).

AIR *Pollution* CONTROL *Is* GOOD BUSINESS*

WILLIAM R. BRADLEY, Chief, Industrial Hygiene Section,
Central Medical Department, American Cyanamid Co.

Public awareness of pollution, both air and stream, seems to have reached an all time high. Moreover, this concern for the subject is being stimulated almost daily in countless ways across the country. Whether it evidences itself in a comic vein, as when Groucho Marx reminds millions of Americans about "smog in Los Angeles" —or when it serves an enterprising reporter on a metropolitan daily writing on the possible link between lung cancer and air pollution—the end result is the same in its significance for us and the companies and organization or governmental bodies we serve.

Pollution and its control or abatement is a matter of vital public interest. And for us involved in industry, it is manifest that pollution control is good business. And as facts demonstrate, it is *vital* for business!

The face of America is changing. Industry is being pressed to disperse its manufacturing facilities by a variety of influences: These include national defense, growth of new markets, new sources of supply and man power, and many others.

The explosive growth of population all over America has presented industry, and especially my own, the chemical industry, with vital public relations problems. In many cases, these problems can affect its future or very existence.

Corporations contemplating expansion of existing facilities, or creating new plants in new locations, today are finding that many communities are zoning furiously to keep industry at arm's length.

Even when an enterprise is a sizable economic force in a community, it may find little sympathy for its imperative need to expand, with an implied corollary that prehaps the enterprise even ought to go elsewhere. At the same time, some communities—or, if you will, *vigorous* voices in such communities—are demanding compliance with pollution control regulations, that in many cases are based on hysteria, or ignorance of simple industrial facts.

This seems especially to occur in a growing number of communities, so eager to bring in industry as an employer and a potential taxpayer, that they tend to minimize or ignore some of the basic elements of industrialization. And if a minimal air or stream pollution is inevitable in the process, there suddenly seems to emerge hitherto silent local voices demanding the return of the rural beauty, pristine air, or ol' fishing holes left over from pre-industry days.

Many segments of the general public, that is to say, many private citizens and municipal governments, fail to recognize that they cause air pollution in permitting open burnings on dumps, the operation of improper incineration and smoke and fly ash from improper combustion of fuel and that the solutions to their problems are known, and have been proved by testing and by experience.

Nevertheless, we find increasingly, the enactment of federal, state and local legislation against pollution, with industry singled out often as the sole or dominant culprit. We see the expenditure of ever increasing sums of money in research on methods of evaluation and in techniques for abatement. Also, we continue to see with growing frequency, episodes of litigation because of actual or potential pollution.

It is apparent therefore that a new approach by industry to the problem of pollution control must be inaugurated. It is necessary that industry recognize pollution when it exists, and act in a positive manner toward abatement.

For the chemical industry, at any rate, the day is past when pollution can be ignored until someone complains about it. We feel that this old philosophy is now out of date and should be discarded. The record shows that in case after case where industry has failed to recognize pollution problems, the matter has been taken out of its hands and brought into the courtroom.

And the public relations record will confirm how often an apparently obscure pollution litigation in a single plant location will be publicized in the press of a thousand communities across the nation. For a corporation doing business in many of these communities, the lesson is unmistakeable and filled with harsh implications.

Today we live in an America increasingly sensitive to the concept of industry in a community functioning as a *corporate* citizen. This means among other obligations that we should conduct our plant operations with due consideration for the nature of the process and the economics involved; and to minimize inconvenience and nuisance to the community. We should also be alert to our responsibility of keeping the community reasonably informed as to our philosophy, problems, and progress. This includes our own employees, too, whose natural pride in a pollution-free operation is important. For after all, they are our most vital contacts with the community itself.

Cyanamid has found that such a positive approach—call it philosophy, if you will—is successfully dealing with most pollution problems. This approach to a common problem is the result of a lesson taught over and over again. However, it has not, in my judgment, been learned or embraced as yet, unfortunately, except by too few industries.

This new approach calls for ten steps. And it is our experience with its attendant benefits, that compels me to predict that if these steps are adopted by any industry or organization, such positive efforts will return sizable dividends

* Presented at the Air Pollution Control Association Annual Meeting, Sheraton Hotel, Philadelphia, Pa., May 25–29, 1958.

of good will and mark its practitioners as leaders in pollution abatement. And may I add, that in view of the growing public concern toward pollution, recognition of such leadership reflects not only good citizenship but also greater support for industry on the part of the community when dealing with other problems.

The ten steps are as follows:

1. Determine by sampling and study if a pollution problem exists. In this connection work closely and confidently with official pollution control agencies.
2. If we have a problem, recognize it, for pollution cannot be easily concealed.
3. Begin control studies through stack sampling, and general air and/or water sampling.
4. Begin a public relations program advising the community of such work.
5. Using the data obtained, begin research on methods for control through pilot studies.
6. Apply the results of research to engineering development of control facilities.
7. Install proved and tested control equipment.
8. Keep the plant neighbors informed of progress.
9. Invite the public to inspect the accomplishment and to celebrate the success.
10. Inform companion industries of pollution control techniques that may be useful to them.

As part of this philosophy we must recognize that it is possible to prevent air pollution before it occurs. It is the policy of the American Cyanamid Company that new processes, expansions, and future planning be reviewed for the adequacy of air and stream pollution control by specialists who make recommendations to executives empowered to act. Our research personnel must anticipate pollution control steps in developing new processes. Control equipment can and is being designed and tested, and is being added to engineering blueprints for new plant construction and for changes in existing processes.

In other words, engineering does not proceed until pollution questions have been answered by the application of the most modern control techniques.

Out of the planning by various Cyanamid groups for new facilities are developed estimates of pollution control costs. These are included in projected operating costs for the new unit, thus insuring that pollution control will be part of day-to-day operations.

Close co-operation with state and other governmental and civic bodies dealing with pollution control is another phase of Cyanamid's approach in its relations with plant communities.

Cyanamid also makes it a practice to be frank on questions of pollution control. We exchange technical information with others in industry. We endeavor to keep regulatory authorities and the community advised of progress through inspection of our control systems by state officials, public groups, and the press.

Our company has also welcomed the establishment of reasonable standards and methods for the control of pollution under state auspices. Cyanamid also regards it as desirable corporate public relations to serve as a *catalyst* in educating the public to the latter's responsibility to join in control measures.

As a result, our company has taken the initiative in making available the services of its specialists in air pollution and industrial hygiene, to work with, and to assist official, local, and state pollution control commissions empowered to carry on effective education and regulatory activities. Such cooperation has already been extended to the Air Pollution Control Commissions in New Jersey and Florida.

Before proceeding to illustrate through actual examples how this philosophy has been carried out in various Cyanamid locations, I should like to re-emphasize the two basic supports that have made our activities possible and effective:

1. Company-wide interest and participation that embraces Cyanamid personnel representing production, insurance, claims, medical, industrial hygiene, engineering, research, legal, public relations, and budget.

2. Vigorous public relations based on actual pollution control *accomplishment*, that helps dispel mystery, ignorance or misunderstanding where it exists.

Case A

For more that 40 years, Cyanamid has been one of a number of companies mining phosphate rock in an area in Brewster, Fla. Phosphate is an important fertilizer. For a long time its mining and processing stood near the top in Florida's economy, both in dollar value and employment. Over the years, citrus growing, cattle raising, and of course tourists and retired Americans have transformed the state to such an extent that the phosphate industry, while still substantial, no longer finds itself so prominent.

As the areas around the mining sites turned residential or became citrus groves, the phosphate companies were increasingly criticized for allegedly polluting the air and streams, and imperiling the health of humans, animals, and plant life.

An appeal for governmental intervention promptly brought legislative hearings, with a view to bringing about the enactment of regulations to control or even to curb the entire phosphate industry.

This constituted a Cyanamid problem of the first order, inasmuch as our company was preparing to build a unit at its Brewster mining operation to upgrade its rock into triple superphosphate, as was being done by some of the other local companies. The making of this improved product results in fluorides and other emissions.

In line with company policy, Cyanamid was resolved that its processing would have to be strictly controlled to prevent or mitigate any air pollution. Over the years, Cyanamid, under the supervision of its able manager, had carried on a very effective community relations program. It was his considered opinion that the new production unit would create no problems by following company policy and public relations procedures.

The following chronology illustrates how Cyanamid's ten point philosophy was carried out.

Immediately upon the approval of the project by management, consultation began with Cyanamid air and water pollution control specialists to ensure that the latest developments for controlling pollutants were embodied in the plant engineering designs.

One year before completion of the new unit, sampling stations were established on the plant site to measure and record the presence in air and water of dusts too fine, and of gases present in too low concentration to be detected by previously existing equipment.

The study will continue for five years. It will provide information for Cyanamid's operations. Equally important, it will provide information for other area phosphate companies and for public agencies, for it will yield the most comprehensive data ever assembled on what actually is in the air and water of the area.

It should be emphasized that arrangements for the air and stream samplings were made with representatives of the Florida State Board of Health and the University of Florida. These specialists and officials were consulted at various stages in planning the program, developing the equipment, and finally invited to observe the equipment in operation. Emphasizing the extent to which Cyanamid felt its responsibility in dealing with these problems, we co-operated in the Air Pollution Control Conference sponsored by the University.

Cyanamid next arranged for an on-the-spot tour of the air sampling stations and the plant site by a group of 22 area reporters and broadcasters. In addition to comprehensive news re-

leases and photographs, Cyanamid personnel discussed the problems openly and the steps taken to solve them. Publicity was extensive and gratifying. For example, the Tampa television station sent over a two-man film and sound crew and devoted one third of its evening news programs to Cyanamid's pollution control efforts. An influential editorial writer praised Cyanamid for "recognizing the community's pride in its lakes and rivers, and its grave concern over the possibility of pollution." And in a state where tourism and recreation are page one news, fishing columnists in papers remote from Brewster, saluted Cyanamid for its "good citizenship."

As you know, I am not a public relations technician. Yet you will find me as emphatic as any newspaperman in emphasizing the necessity of telling your story. It would almost seem to be a truism, but the record confirms so often that when a community reacts unfavorably to an industrial situation, ignorance or simple lack of information lies at the root from which the tree of hostility grows.

For example, it became apparent that despite the fact that the phosphate industry had been around a long time and was still the largest economic unit in the area, and public had a very meager understanding of the industry's contributions in payrolls, job opportunities, purchasing power, and the benefits derived from its chemical products.

Our company was invited to co-operate with the local newspaper in its preparation of a series of eight articles. These provided for the first time in the area, an up-to-date and factual account of the industry's importance and problems. They deal with a history of phosphate mining. They emphasize how technology and new capital have modernized the industry to provide many new jobs and other economic benefits.

There is even an article on the public relations problems of the phosphate industry in which our pollution control program and "open door" policies were singled out for commendation. When you have invested millions of dollars in a plant expansion under such circumstances, it is good to feel you are wanted!

It might be noted in passing that Florida has enacted an Air Pollution Control law, under which Cyanamid can operate profitably and has so stated publicly.

It seems to be one of the axioms of chemical industrial life that pollution problems will continue to loom high, respecting neither plant location nor size nor time. For, as previously noted, America's population is moving explosively.

Case B

In a midwestern state, Cyanamid operates an acid and alum production unit that today lies on the outskirts of a city of 60,000. In fact, we're just across the city line. Twenty years ago, when Cyanamid built the plant, the nearest residence was several miles away with farms in between. Over the years, the corn fields turned into real estate developments. Today, houses march almost up to Cyanamid's front gate.

In the old days, the occasional discharges from the stacks when winds drove down the mist were dissipated over empty fields and constituted no problem and generated no hostility.

Some months ago the plant installed a new, more efficient acid-making unit, taking all proper precautions and making use of stack and air sampling evaluations. Unfortunately, atmospheric condition and the winds paid little attention to the virtues of the new process. When the mists drifted downward, they encountered the new housing and its residents, most of whom it turned out knew very little about its neighbor, Cyanamid. The fact is that we had overlooked to some degree the value and necessity of telling our local story.

Letters and phone calls of protest followed. A petition was signed by a sizable number of residents and delivered to the local newspaper and the City Health Director. It is a measure of the good will and sense of the press and the health official that they resisted the pressure to make a public outcry, until they had consulted Cyanamid.

In several meetings at the plant attended by city and state representatives, Cyanamid's situation was clarified with company pollution control specialists present to provide full information. The air sampling program was expanded and additional process control measures were installed.

Yet the most important decision it would seem was the vigorous program of community relations undertaken to remedy the lack of information about Cyanamid. News stories have been published. Exhibits dramatizing the plant and its personnel and products have presented Cyanamid as a desirable corporate citizen in the area. Liaison has been established with appropriate community leaders and local residents. And when the air sampling tests are completed, Cyanamid contemplates an open house to allow its neighbors to visit the plant and see for themselves. What have we proved here? That an effective community relations and information effort must march hand in hand with pollution control measures.

I have devoted a good deal of time to this area of public relations. Yet, as noted previously, unless you are prepared to deal realistically with pollution

determine
DUST PARTICLE
SIZE DISTRIBUTION
below 60 microns

Micro-Particle Classifier No. 6000 with totally enclosed 220 volt, 3 phase motor operates at 3500 rpm. 16" high x 16½" diameter

with the
DIETERT-DETROIT
MICRO-PARTICLE
CLASSIFIER

Quickly determine sub-sieve particle sizes with scientific accuracy. The No. 6000 Dietert-Detroit Micro-Particle Classifier is widely used throughout industry for pre-testing dust collector needs, for determining the separating efficiency of air cleaners, for particle size control in many industrial processes and for scientific studies of fine materials. Mineral flours, metal powders, abrasives, fly ash, chemicals, drugs, etc., can be classified into eight fractions below 60 microns, (materials above 60 microns can be retained for sieve analysis). An eight-fraction analysis can be completed at the rate of 15 minutes per fraction by unskilled operators. Fractions are precisely defined and may be retained for accurate study. Gentle sifting action prevents particle fracture—assures accuracy and reproducibility.

8-page catalog mailed on request

HARRY W. DIETERT CO.
CONTROL EQUIPMENT
9330 Roselawn Detroit 4, Michigan

Send me 8 page Micro-Particle Classifier bulletin—without obligation.

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

WHIRLEX Dust Collectors are *Made to Order*

Typical is this specially designed dust collector for a major Southern paper mill. The unit was designed to fit limited space and works in conjunction with a bark fired boiler. Maximum fuel efficiency is attained with a special WHIRLEX re-injection system. The system returns cinders to the boiler while sand and other foreign matter is disposed.

A WHIRLEX system may save you money too . . . write for complete information.

Fly Ash Arrestor CORPORATION
210 North 1st. Street • Birmingham, Ala.

Dust Collectors | Induced Draft Fans | Forced Draft Fans
Exhaust Fans | Self Supporting Stacks | Duct Work

WHIRLEX

where it exists, all the communication skills in the world will be meaningless. Words can only follow deeds in the lexicon of pollution control.

I should like therefore to wind up my remarks with some observations on how management interest in pollution prevention can be obtained throughout one's company or organization. In my judgment, such interest must be widespread through your group. Obtaining such interest is primarily a matter of conference, discussion, and explanation.

It is the result of establishing company-wide participation in a study of an actual pollution problem. Call it education if you will.

The first step in the educational process is to select an existing serious problem and work up a complete case against yourself. Then with the facts at hand, you are ready for a series of conferences aimed at leading ultimately to a decision on procedure.

With the facts at hand, the seriousness of the situation can be determined. Such facts are necessary, of course, in order to know the extent of the problem, and must be available to design engineering control. The costs for process improvement and for the purchase, installation, and operation of control equipment can be estimated. The number of persons involved in the pollution episode may be determined and the potential cost of litigation and damage claims can be closely estimated.

A series of conferences called to present the facts is the second step. They will include company personnel representing legal, public relations, production, insurance, claims, medical, industrial hygiene, engineering, research, safety, and budget. As a result of conferences, a plan of action should be authorized and then executed. If the facts, thus presented, do not speak for themselves, then eventual litigation will. Many pollution problems can be evaluated by the above techniques and, when presented in such conferences, each company department may learn how the problem affects them and can determine its particular responsibility. Published reports of the conferences and the decisions made may be circulated to increase company-wide awareness of pollution problems. The philosophy of the positive approach to pollution abatement should be stressed throughout these conferences and reports until it becomes a generally accepted part of company thinking and the basis on which decisions are made.

The procedure of securing facts and presenting them for open discussion has resulted in interest and action in our company. By this process a continuing experience is had by all concerned in gaining information and in

becoming aware of the total pollution problem within the company. At the same time, something is learned about the problems of others in the industry. Interest and understanding have spread to the point where it is generally recognized that scientific facts can be obtained to tell us that we either have a pollution problem and that it is possible to find a solution and apply control, or that none exists. Also, it becomes generally realized and accepted that it is possible and desirable to abate a nuisance before it occurs when designing and constructing new plant facilities. By this preventive procedure we are not forced to curtail or stop production due to litigation.

In a large chemical manufacturing enterprise like Cyanamid, with scores of plant locations and substantial investment, this positive approach to air pollution control based on realistic control measures and public relations practices has proved to be good business.

Classified

POLLUTION ABATEMENT ENGINEER. Desire BS or MS Chemical or Electrical Engineer. Minimum five years experience in Pollution Abatement Control or in design and testing of control equipment. Position requires some traveling. Salary commensurate with degree and experience with good opportunity for advancement. Leading research laboratory, Pittsburgh District. Forward complete resume of training experience, and salary requirements to Publications Department, Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh 13, Pa.

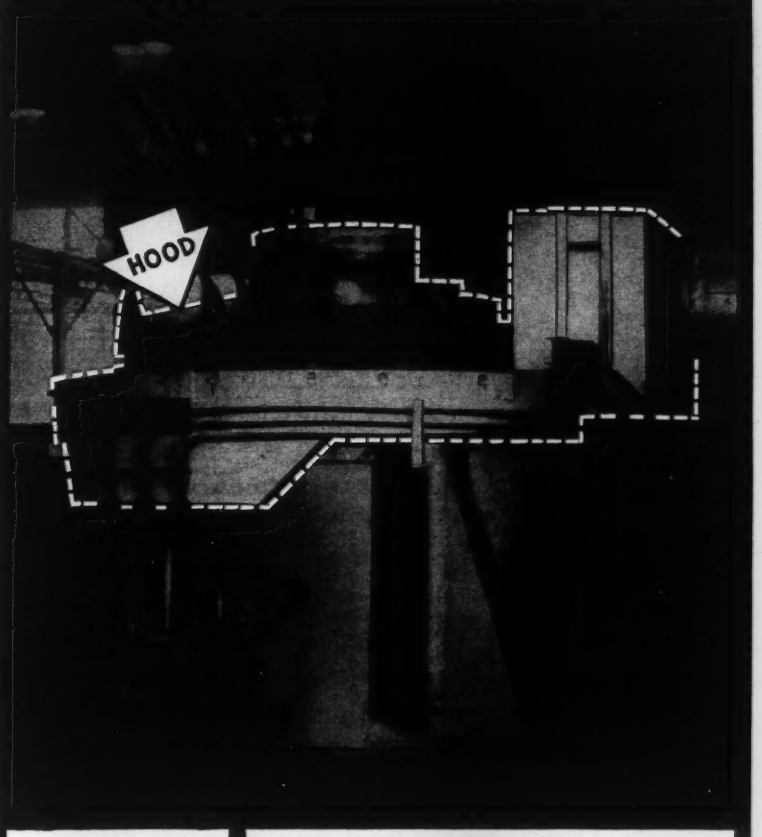
* * *

SENIOR RESEARCH SCIENTIST, Air Pollution, New York State Department of Health, Division of Laboratories and Research, to assume technical supervision of laboratory activities in air pollution control. Must have undergraduate degree in chemistry and graduate work in air pollution field plus one or two years of professional experience. Experience may be substituted for graduate study. Noncompetitive Civil Service. Starting salary $8650 with five annual increments to $10,362 maximum. Reply to W. W, Sanderson, Division of Laboratories and Research, New Scotland Avenue, Albany, N. Y.

THE EMBLEM

The loop around the outside stands for purification. The "window" in the center is one of the symbols for air. And the surrounding dots signify dust, ashes, and other forms of particulate matter—by extension, air contaminants. The symbols are taken from alchemy.

CONTROL ELECTRIC FURNACE FUMES



Pangborn offers a new concept in electric furnace exhaust hoods!

After years of development, Pangborn now offers effective control of smoke, fumes and dust from electric melting furnaces with minimum interference to furnace operations and maintenance. The hood design is based on the fundamental dust control principle of confining and capturing fumes and dust immediately adjacent the source. Effective control is secured with substantially reduced exhaust air volumes.

The Pangborn Exhaust Hood reduces the weight carried by the furnace roof; reduces hood areas subject to high temperatures; reduces electrode travel limitations and is applicable to top and side charge furnaces of all types and sizes.

With the exhaust hood connected to an efficient Pangborn Cloth Bag Collector, compliance with the most rigid air pollution control regulations is assured. For information call the Pangborn man in your area or write: PANGBORN CORP., 5100 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

Pangborn CONTROLS DUST

DAY "AC" Dust Filter and DAY Dual-Clone in the Stauffer Chemical Company fertilizer plant located in Tacoma, Washington

THIS DAY DUST CONTROL EQUIPMENT CERTAINLY SOLVED OUR DUST PROBLEM!

DAY Supplies Dust Control Equipment for Practically Any Industrial Need

The DAY "AC" dust filter* (shown above) captures submicron particles with 99.99+% filtering efficiency. This filter is used in many plants throughout the United States and Canada and handles a wide variety of materials including aluminum, cement, chemical, food, pharmaceutical, porcelain, radioactive, rubber and many other dusts.

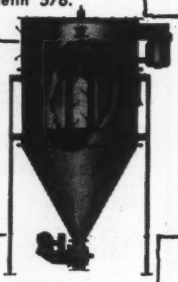
The DAY Dual-Clone (above-right) has low horsepower requirements and operates with unusually low back pressure. It requires no maintenance.

For latest information about DAY "AC" and Dual-Clone equipment write toDAY for Bulletins 559 and 49-DC.

*Licensed by H. J. Hersey, Jr.

DAY TYPE "HV" CYCLONIC SEPARATOR

A heavy gauge, welded, high efficiency cyclonic separator. The DAY "HV" has a wide range of applications. It handles abrasive or high temperature dust laden air and requires no maintenance because it has no moving parts. Available for pressure or vacuum operation. For additional information write for Bulletin 576.



DAY TYPE "RJ" DUST FILTER*

A packaged dust filter shipped completely assembled and ready to run. Provides high performance, top efficiency dust control at low cost. High air-to-cloth ratios give extra air handling capacity in small area. Furnished with or without dust fan and discharge equipment. For latest information write toDAY for Bulletin 560.

*Hersey and DAY patents applied for.

DAY TYPE "G" EXHAUST FANS

High air delivery per horsepower required. These fans are designed specifically for dust control applications. Each fan is statically and dynamically balanced before shipment. For further information write toDAY for Bulletin 471.

The **DAY** *Company*

SOLD in UNITED STATES by
The DAY SALES Company
862 Third Avenue N.E.
Minneapolis 13, Minnesota

MADE and SOLD in CANADA by
The DAY Company of Canada Limited
Rexdale (Toronto), Ontario, Canada
Ft. William, Ontario, Canada

Representatives in Principal Cities

EQUIPMENT ONLY OR A COMPLETE SYSTEM

(*Continued from page 95*)

"The public is prone to think of air pollution control in too small terms. Adequate control of air pollution is really a major community housekeeping project. It should be considered in the same manner as keeping roads and streets paved, clean, and in repair, providing an ample supply of safe water, providing an adequate system of sewage and waste disposal, and maintaining a good moral atmosphere. Another requirement is continuity of the work. There should be no let-up in the effort. Too many communities would like to eliminate atmospheric pollution but are not willing to pay the price—in money or in effort."

Appendix

Air Emissions Survey

Dear Mr. _____ :

The Head of each Operating Department is rquested to develop the following information:

1. Summarize and tabulate all wastes, gaseous or particulate, at present being discharged to the atmosphere from the buildings and operating areas under his jurisdiction. The waste sources will include still and reactor vents, tank vents, smoke stacks, compressor discharges, etc., etc. The data will cover the following required items:

   a. Quantity of organic and/or particulate material involved in each stream, in pounds per day or month, whichever is most convenient.
   b. Volume of waste stream in std cu ft/min.
   c. Pressure and temperature at which it is vented.
   d. Other information such as range of variation, whether continuous or batch, etc.

2. Your suggestions and recommendations as to how the waste materials may be reduced in quantity at the source, or disposed of to reduce atmospheric pollution.

This information is to be turned over to the writer for compilation. The purpose of this outline is to secure uniformity in the information obtained.

REFERENCES

1. APCA Abstracts, Air Pollution Control Association, Pittsburgh, Pa.
2. Air Pollution Abatement Manual, Manufacturing Chemists' Association, Inc., Washington, D. C.
3. American Petroleum Institute Manual on Disposal of Refining Wastes, II, Gases and Particulate Matter, Fifth Edition.
4. P. L. Magill, F. R. Holden, and C. Ackley, eds. Air Pollution Handbook, McGraw-Hill, (1956).
5. W. G. Christy, "Industrial Air Pollution," *Industrial Wastes* (September-October, 1958).

Invitation for Submission of Papers

53rd ANNUAL MEETING
of the
AIR POLLUTION CONTROL ASSOCIATION

NETHERLAND-HILTON HOTEL, CINCINNATI, OHIO
May 22–26, 1960

Papers for presentation at this meeting are being solicited, and any interested authors should submit, before November 15, 1959, three copies of the title and abstract to the Chairman of the Committee on Technical Papers and Program:

Arthur C. Stern
Robert A. Taft Sanitary Engineering Center
U. S. Public Health Service
4676 Columbia Parkway
Cincinnati 26, Ohio

If your paper is selected for presentation by the Committee—three copies, including one clear-cut black original suitable for photographic reproduction, of the complete manuscript must be sent to Mr. Arnold Arch, Executive Secretary of APCA, Pittsburgh, Pennsylvania, not later than March 1, 1960. This will permit preparation of preprints of all papers in time for distribution at the meeting.

Papers submitted for this meeting may not be offered for publication elsewhere than the *Journal of the Air Pollution Control Association* unless specific written release is obtained from the Association. The Association will, however, give the author not later than three months after the date of presentation of the paper either a firm commitment that the paper will be published in the *Journal* of the Association or a release for publication elsewhere.

Index to Advertisers

Beckman Instruments, Inc.	Inside Back Cover	Fly Ash Arrestor Corporation	118
Beckman & Whitley Inc.	Inside Front Cover	Lauren B. Hitchcock Associates	109
Buell Engineering Company, Inc.	73	Pangborn Corporation	119
Buffalo Forge Company	122	Research Appliance Company	123
Day Company	120	Research-Cottrell, Inc.	98–99
H. W. Dietert Co.	117	The Staplex Company	74
Ducon Company, Inc.	76	Western Precipitation Corporation	121

Next Issue . . .

The November issue of the *Journal of APCA* will feature the publication of the Technical Manual on Single Retort Underfeed Stokers. This Manual includes Standards, Recommended Practices, Technical Information, and Operating Instructions. The preparation of this manual was co-sponsored jointly by the Stoker Manufacturer's Engineering Committee and the Air Pollution Control Association, through APCA's Technical Co-ordinating Committee TA-6.

In addition to the Stoker Report, the Journal will contain articles on the following topics:

1. Critique of the article: "Effectiveness of Odor Counteractants for the Treatment of Stack Gases," which appeared in the May, 1959 *Journal of APCA*.
2. Meteorological considerations in air quality planning.
3. Discussion of an automatic atmospheric fluoride analyzer with reference to its potential application to other pollutants included.
4. A case study of the public relations program of a large company in Utah.

These are only a few of the many interesting topics that will be presented in the coming issue.

CALENDAR

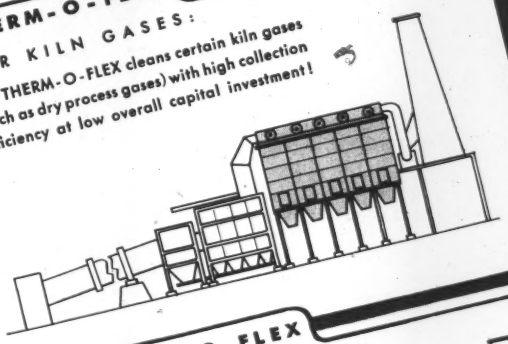
Sept. 21–Oct. 2	P.H.S. training course, "Community Air Pollution," Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
October 20–23	Diamond Jubilee International Clean Air Conference and Exhibition, National Society for Clean Air, London, England
Nov. 30–Dec. 11	Course in Air Pollution, Institute of Industrial Medicine, New York University Post-Graduate Medical School.

WESTERN PRECIPITATION'S NEW THERM-O-FLEX COLLECTOR

CLEANS GASES TO 550°F with VIRTUALLY 100% COLLECTION!

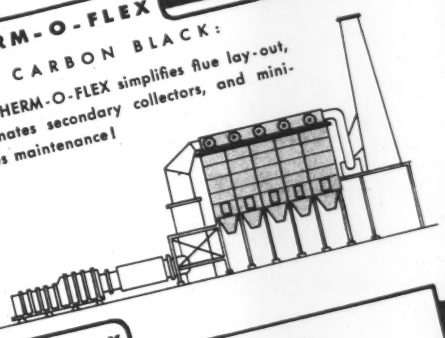
THERM-O-FLEX FOR KILN GASES:

The THERM-O-FLEX cleans certain kiln gases (such as dry process gases) with high collection efficiency at low overall capital investment!



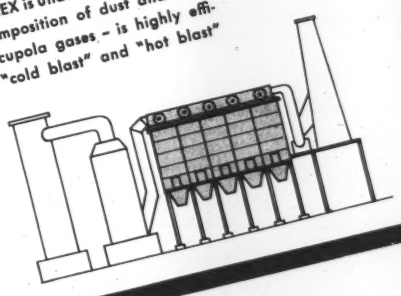
THERM-O-FLEX FOR CARBON BLACK:

The THERM-O-FLEX simplifies flue lay-out, eliminates secondary collectors, and minimizes maintenance!



THERM-O-FLEX FOR CUPOLA GASES:

The THERM-O-FLEX is unaffected by the varying chemical composition of dust and fume particles from cupola gases – is highly efficient on both "cold blast" and "hot blast" processes!



Western-Precipitation brings another important new advancement to the gas cleaning field — the THERM-O-FLEX Collector — a filter type of unit with many advantages over conventional filter equipment...

- The THERM-O-FLEX features glass silicone treated filter tubes that efficiently handle gases as hot as 550° F!
- The THERM-O-FLEX tubes are cleaned *automatically* by intermittent collapsing (not by destructive shaking). This assures uniformly low pressure drop combined with long filter life!
- The THERM-O-FLEX has *no moving parts* — nothing to require frequent servicing or replacement!

RESULT — highest collection efficiency combined with lower cost, less maintenance and uniformly low pressure drop on a wide range of applications, a few of which are shown at left.

Let Our Experienced Engineers study *your* dust or fume collection problem — *large or small* — and show exactly how **THERM-O-FLEX** gives new standards of performance at low installation costs. No obligation, of course!

HELPFUL NEW BULLETIN describes multiple Therm-O-Flex savings, outlines applications, technical data. *Ask for Bulletin #F105!*

COTTRELL Electrical Precipitators
MULTICLONE Mechanical Collectors
CMP Combination Units
DUALAIRE Jet-Cleaned Filters
THERM-O-FLEX Hi-Temp Filters
TURBULAIRE-DOYLE Scrubbers
HOLO-FLITE Processors
HI-TURBIANT Heaters

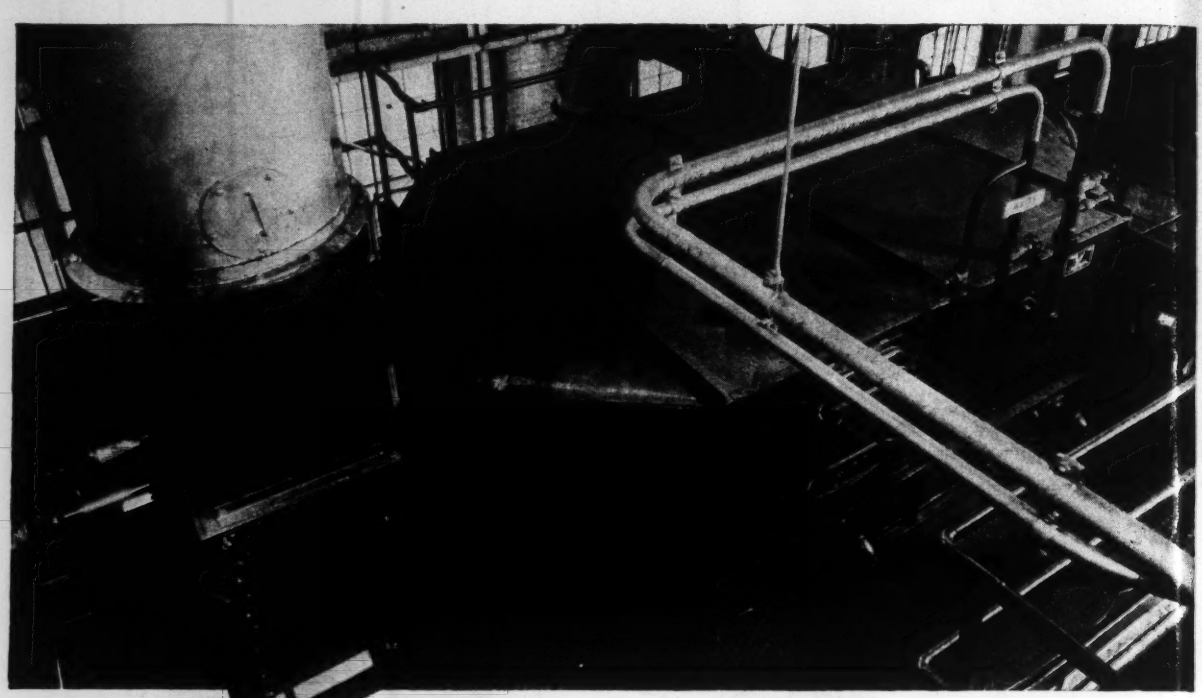
WESTERN PRECIPITATION CORPORATION

Engineers and Constructors of Equipment for Collection of Suspended Material from Gases . . . and Equipment for the Process Industries

LOS ANGELES 54 • NEW YORK 17 • CHICAGO 2 • PITTSBURGH 22 • ATLANTA 5 • SAN FRANCISCO 4

Representatives in all principal cities

Precipitation Company of Canada Ltd., 8285 Mountain Sights Avenue, Montreal 9



Typical Installation of "Buffalo" Gas Absorber.

PVC lined gas absorber for handling aqua-regia fumes.

LICK THOSE DIFFICULT ACID MIST EFFLUENT PROBLEMS with "BUFFALO" GAS ABSORBERS

- **Highly efficient**
- **Low air flow resistance**
- **Minimum maintenance**
- **Easy installation**
- **Low operating cost**
- **Compact and lightweight**

"Buffalo" Gas Absorber washers are extremely efficient air pollution control units capable of collecting acid mists and inert particulate material. Utilizing beds of wetted fibers they are finding wide use in treating effluents from such difficult applications as laboratory hoods and open surface tank operations.

Construction of the unit makes it suitable for a wide range of applications. Specific characteristics of the process gas to be treated and the degree of cleaning required will determine the type and number of cleaning stages in the "Buffalo" Gas Absorber. Three distinct gas cleaning components which may be found are: 1. wetted impingement-type cells for removal of particulate materials which would plug fibers if permitted to pass. 2. wetted fiber cells for absorption of gases. 3. dry fiber cells for elimination of fine droplet carry-over from the unit.

The many features of cost, effectiveness and versatility of the "Buffalo" Gas Absorber make it a wise choice for your air pollution control problem.

Investigate the many advantages of "Buffalo" Gas Absorbers *today!* Write for Bulletin AP-225.

"Buffalo" Can Solve YOUR Air Cleaning Problems!

We manufacture a wide line of air cleaning equipment to control many types of air pollution. Your nearby "Buffalo" engineering representative will be glad to analyze your problems and make recommendations. Call him now, or write us for full information.

BUFFALO FORGE COMPANY

Buffalo, N. Y.

Buffalo Pumps Division, Buffalo, N. Y. • Canadian Blower & Forge Co., Ltd. Kitchener, Ont.

VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING • FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING

In Charlotte, North Carolina

A. I. S. I. SAMPLER readings reveal year-to-year improvements in AIR POLLUTION CONTROL

By making a graph of A.I.S.I. Sampler readings in Coh Units, Charles S. Frost, Director of the Charlotte, N. C. Department of Air Pollution Control, maintains an hour-by-hour, day-to-day, and year-to-year record of air pollution conditions in Charlotte.

Results of any air pollution regulations put into effect can be determined almost immediately by reading the A.I.S.I. Sampler recordings.

Charlotte, which is constantly improving conditions in cleaner air, is one of many municipalities throughout the country who are maintaining air pollution records based on the readings of the A.I.S.I. Sampler.

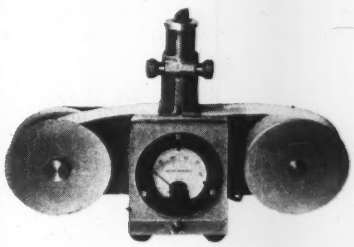
The low cost of the A.I.S.I. Sampler makes it feasible to locate a large number of them for complete coverage of a geographical area; and its quiet operation overcomes any objections to its location in or near individual residences.

Research Appliance Company manufactures another sampler, the A.I.S.I. Hydrogen Sulphide Sampler, which measures the amount of hydrogen sulphide in the air. It can indicate H_2S concentration as low as one part per billion parts of air.

It operates on the same principle as the Air Sampler, but is fitted with an air filter to remove suspended solids; and the tape assembly is enclosed to prevent blackening of the tape, outside the sample spot.

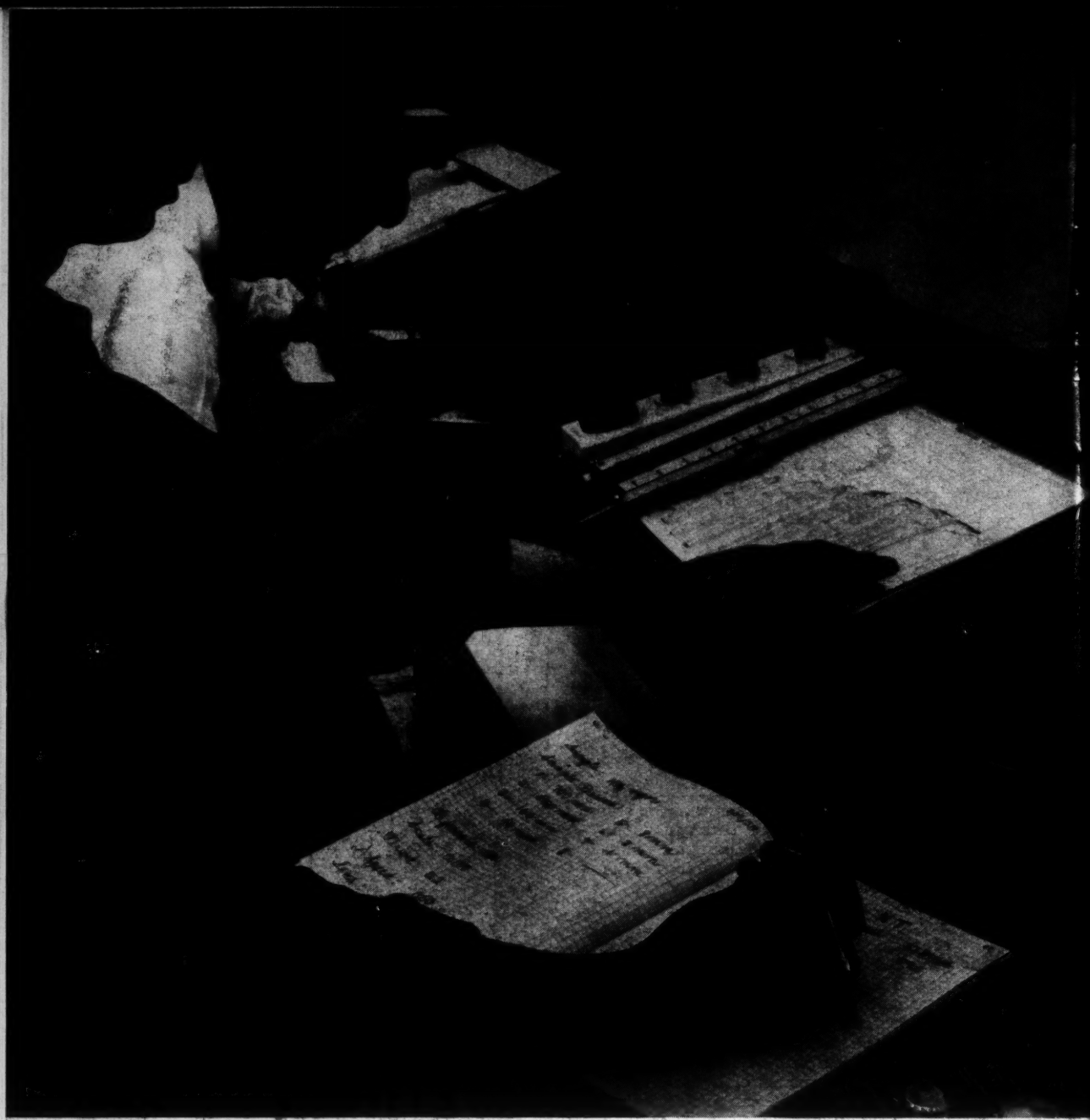
TO ANALYZE THE SPOTS, Research Appliance Company manufactures a Spot Evaluator with which spots are evaluated by measurement of light transmission.

Write for descriptive bulletins that give complete construction and performance details of both the samplers and the Spot Evaluator.



RESEARCH APPLIANCE COMPANY

Box 307 Allison Park, Pa.



More Beckman DK's are used in more applications than all other ultraviolet recording spectrophotometers combined... Why? Because the DK is a laboratory workhorse. ⌑ Because it's simple to use and automatic. ⌑ Because a complete line of accessories and a measurement range of 185 to 3500 mμ make it versatile in use. ⌑ Because it's the lowest priced recording spectrophotometer available. ⌑ And because the DK is sold and serviced from over 75 locations throughout the United States. For detailed specifications on this outstanding Recording Spectrophotometer, contact your convenient Beckman DK dealer or write us for Data File L-601-85.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road, Fullerton, California

It's a Fact: The Beckman IR-4 Infrared Spectrophotometer with 10-meter gas cell identifies and measures air pollutants in minute samples, saving field sampling time while enabling measurement of very low concentrations.